PB-242 827

MANAGEMENT PRACTICES AFFECTING QUALITY AND QUANTITY OF IRRIGATION RETURN FLOW

Larry G. King, et al

Utah State University

Prepared for:

Environmental Protection Agency

November 1974

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PB 242 827

EPA-660/2-75-005
APRIL 1975

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TECHNICAL REPORT DATA
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PB242827

1. REPORT NO. EPA-660/2-75-005	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Management Practices Affecting Quality and Quantity of Irrigation Return Flow		5. REPORT DATE November 1974
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Larry G. King and R. John Hanks		8. PERFORMING ORGANIZATION REPORT NO. EPA-660/2-75-005
9. PERFORMING ORGANIZATION NAME AND ADDRESS Utah State University Logan, Utah 84322		10. PROGRAM ELEMENT NO. 1BB039
		11. CONTRACT/~~GRANT~~ NO. EPA- S801040
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U.S. Environmental Protection Agency Washington, D. C. 20460		13. TYPE OF REPORT AND PERIOD COVERED Final (4-72 to 11-73)
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Field and laboratory research was conducted to determine the effects of irrigation management and fertilizer use upon the quality and quantity of irrigation return flow. The total seasonal discharge of salts from the tile drainage system was directly related to the quantity of water discharged, because the solute concentration of the ground water was essentially constant over time. Under such conditions, reduction of salt content of return flow is accomplished by reduced drain discharge. Irrigation management for salinity control must be practiced on a major part of a particular hydrologic unit so that benefits are not negated by practices in adjoining areas. Field studies and computer models showed that salts may be stored in the zone above the water table over periods of several years without adversely affecting crop yields on soils with high "buffering" capacity as encountered in this study. However, over the long term, salt balance must be obtained. Appreciable amounts of nitrate moved into drainage water at depths of at least 106 cm from the applications of commercial fertilizer and dairy manure to ground surface. Submergence of tile drains in the field reduced nitrate concentrations in the effluent, especially under heavy manure applications. This report was submitted in fulfillment of Grant No. S801040 by Utah State University under the partial sponsorship of the Environmental Protection Agency. Work was completed as of November 30, 1973.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Irrigation return flow, *Drainage, *Salinity, *Model studies, *Soil water movement, *Nitrogen, Sprinkler irrigation		02/03

PRICES SUBJECT TO CHANGE

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 168
	20. SECURITY CLASS *(This page)*	22. PRICE $6.25-2.25

☆ U. S. GOVERNMENT PRINTING OFFICE: 1975-698-270/122 REGION 10

EPA-660/2-75-005
APRIL 1975

MANAGEMENT PRACTICES AFFECTING QUALITY AND QUANTITY OF IRRIGATION RETURN FLOW

By

Larry G. King
Department of Agricultural and
Irrigation Engineering
and
R. John Hanks
Department of Soil Science and
Biometeorology
Utah State University
Logan, Utah 84322

Grant No. S801040
Program Element 1BB039
ROAP 21AYS Task 005

Project Officer

James P. Law, Jr.
Robert S. Kerr Environmental Research Laboratory
National Environmental Research Center
P. O. Box 1198
Ada, Oklahoma 74820

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Field studies and computer models showed that salts may be stored in the zone above the water table over periods of several years without adversely affecting crop yields on soils with high "buffering" capacity as encountered in this study. However, over the long term, salt balance must be obtained.

Appreciable amounts of nitrate moved into drainage water at depths of at least 106 cm from applications of commercial fertilizer and dairy manure to ground surface. Submergence of tile drains in the field reduced nitrate concentrations in the effluent, especially under heavy manure applications.

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ACKNOWLEDGMENTS

Many individuals assisted, encouraged, and supported the work leading to this report. The authors would particularly like to acknowledge the help of Dr. Vaughan E. Hunsaker and Dr. Raymond W. Miller on the nitrogen aspects of the research. Dr. Miller was instrumental in analyzing results of the nitrogen movements. Dr. L. S. Willardson assisted in writing the revision.

The authors express special appreciation to R. B. Backus and R. D. Bliesner who served as farm managers in residence in Vernal for the 1972 and 1973 growing seasons, respectively. Through their efforts smooth operation of the field research was accomplished.

SECTION I

CONCLUSIONS

1. The drain discharge on the Hullinger farm is rather insensitive to irrigation management practices on the farm itself but instead depends upon practices of farmers over a much larger area. Any irrigation management plan for return flow quality control must include the major part of a hydrologic unit in order to be successful.

2. Salt storage in the soil profile above the bottom of the root zone is indicated by the high values of drain effluent EC for small infrequent drain flows. This salt storage is not a direct result of the irrigation management practiced since research work began on the Hullinger farm but has been developed over long periods of time.

3. Water table depth appears to be a significant factor affecting salt storage in the soil profile and return flow quality where water application approaches or is less than evapotranspiration requirements.

4. The total seasonal salt discharge from the tile drainage system was directly related to the quantity of water discharged. Therefore, management of water is the key to successful return flow quality management. Any control plan which will reduce total discharge of water will probably also reduce total discharge of salts, at least over the short term. The period of effectiveness of such a plan is difficult to ascertain but the period would be of several years duration.

5. Precipitation and solution mechanisms play an important role in salt movement through Hullinger farm soils. The soils have a high "buffering" capacity. This supports the foregoing conclusion that quantity of water flow is the controlling factor. Since the EC of the soil solution at any given depth is essentially constant with time under the management variables that have been imposed in this experiment, the salt movement into drains is simply the product of the salt concentration and the water inflow rate.

6. The model developed and used for prediction purposes was limited to simple salt flow where solution and precipitation of salts within the soil were not considered. The model predicted that under several irrigation management variations, yield was not influenced until salt accumulations which took several years occurred. The results predicted were strongly influenced by the presence of the water table and the depth of the plant root zone assumed. Modifications of the model, to account for precipitation, solution and exchange, etc., did not significantly improve the prediction when applied to the Hullinger farm data.

7. Appreciable amounts of NO_3-N moved into drainage water at depths of at least 106 cm from manure additions of 216 mt/ha (dry) or from

commercial fertilizer applications of 440 kg/ha N as $Ca(NO_3)_2$ or NH_4NO_3. Concentrations of over 30 ppm NO_3-N were measured in drain water under the commercial fertilizer plots.

8. Additions of manure at rates of 108 mt/ha (dry) increased NO_3-N content in the soil to levels greater than 20 ppm, even the year after application. This is more than 2 to 3 times NO_3-N concentrations of control plots.

9. NO_3-N reductions during the growing season approached 300 kg/ha for applications of 440 kg/ha N as $Ca(NO_3)_2$.

10. Salt increases were noted at the 106 cm depth under plots receiving heavy manure applications.

11. Submergence of tile drains can reduce NO_3-N concentrations in the effluent. One drain was successfully submerged so that the water table was always at or above the top of the gravel envelope during the irrigation season. The NO_3-N concentration of effluent from this drain was significantly lower (by a factor of about 1/2 to 1/4) than the drain receiving the same fertilizer application but flowing freely and having air within the drain pipe.

SECTION II

RECOMMENDATIONS

1. The results of this study indicate that with approximately yearly monitoring of soil salinity status and appropriate irrigation management, salt can be stored in the soil profile for several years with little yield decrease. However, over the long period of time salt balance must be maintained. For soils with little "buffering" capacity, the model predictions indicate that irrigation management procedures are available that will allow yield maintenance with no drainage for a few years.

2. The soils like those on the Hullinger farm will allow salt storage in the profile with no drainage, with little yield decrement, because large amounts of salt are precipitated with a minimum of salt buildup. With yearly monitoring of salinity status it is probable that a no-drainage system would function satisfactorily for approximately 10 years before significant yield decreases would result. However, over a long time, salt balance would have to be maintained.

3. Highly buffered soils, like those studied from the Hullinger farm, will load the drainage water with soluble salts in direct proportion to the drainage water amount since the soil solution concentration is essentially constant. Yearly monitoring of the soil solution concentration in the drains would appear to be sufficient to predict the salt load provided the water flow can be measured. Additional research is needed to characterize the soil physical and chemical properties of these highly buffered soils.

4. Prediction of water flow into the drains based on predictions of evapotranspiration, irrigation amount, precipitation and soil water storage will probably have an error of about 100 percent. This is due to errors of about 10-20 percent in predicting evapotranspiration and soil water storage, and nonuniform irrigation and rainfall. Thus it is unlikely that low leaching irrigation management schemes can be attained on a farm field scale.

5. Significant decreases in salt flow into the drainage water without yield decreases in a region like the Vernal, Utah site can be attained by decreasing the leaching of the present irrigated farms (estimated to be 10-100 percent of irrigation requirement). However, this will only be possible (if the site studied is representative) by conversion of the present valley-wide gravity irrigation system, with a poor irrigation uniformity, to a system capable of much more uniform water application. While it is questionable whether this conversion would be economically feasible under present conditions for the local farmers, with the many human factors that would cause problems, this type of solution would surely compare with the alternative solution of desalinization plants.

6. It is recommended that any procedures suggested to control irrigation return flow be applied to complete hydrologic units. The results reported herein show that drainage flow and quality on the experimental farm were almost entirely controlled by irrigation of surrounding farms.

7. It is recommended that an irrigation management system involving several years of salt storage with no drainage, be followed by a leaching period to minimize nitrate movement into the drainage water and maximize use of the NO_3-N fertilizer. The most efficient use of such a system would require periodic salinity and nitrate monitoring and control of fertilization and irrigation water application.

SECTION III

INTRODUCTION

Irrigated agriculture has historically been concerned with water supply, diversion and conveyance of water to the farm, and use of water on the farm. The disposal or return of excess water to the stream was a point of lesser concern. The main emphasis has been on quantity rather than quality of water. Salinity has long been recognized as an important parameter influencing the suitability of water for use as an irrigation supply. The amount and kinds of salt existing in soils have been used for assessing their suitability for receiving irrigation water. In all of these activities, attitudes of persons involved have usually been that the quality of the irrigation return flow was not of too much consequence or that it was a natural result of activities necessary for the maintenance of the agriculture of an area and not subject to much control.

The salinity problem in the Colorado River Basin is emphasized by a report (EPA, 1971) the conclusions of which include:

1. Salinity (total dissolved solids) is the most serious water quality problem in the Colorado River Basin.

2. Salinity concentrations in the Colorado River system are affected by two basic processes:
   (a) salt loading, the addition of mineral salts from various natural and man-made sources; and
   (b) salt concentrating, the loss of water from the system through evaporation, transpiration, and out-of-Basin export.

3. Salinity control in the Colorado River Basin may be accomplished by the alternatives of:
   (a) augmentation of Basin water supply;
   (b) reduction of salt loads (including improvement of irrigation and drainage practices);
   (c) limitation of further depletion of Basin water supply.

Irrigation return flow constitutes a very large part of the water influent which reaches the streams and rivers of the Colorado River Basin. Thus, salinity and irrigation return flow are vitally linked in the overall problem. Indications of the importance of the problem are given by several recent events including, but certainly not limited to, the following:

1. The aforementioned report on the mineral quality problem in the Colorado River Basin;

2. The February 1972 sessions of the Federal-State Enforcement Conference on the Colorado River held in Las Vegas;

3. Discussions of Colorado River salinity problems between the Presidents of the United States and Mexico;

4. The Western Regional Research Project, W-129, entitled "Salinity Management of the Colorado River Basin" supported by the Agricultural Experiment Stations of the seven Basin states and the Cooperative State Research Service;

5. The National Conference on Managing Irrigated Agriculture to Improve Water Quality held in Grand Junction, Colorado, May 1972;

6. The decision to build a desalting plant near Yuma, Arizona, to handle the effluent from the Welton-mohawk project.

It was concluded (EPA, 1971) that salinity control in the Colorado River Basin may be accomplished in part by improvement of irrigation and drainage practices. Evaluation and preassessment of such improved practices depends upon knowledge of water and salt movement through the root zone of the crops. Return flow of water to streams from irrigation water applied to fields is profoundly influenced during its flow through the soil. There is, first of all, decrease in the amount of the irrigation water that might appear as return flow because of vapor loss to the atmosphere during the evapotranspiration process. The amount of water returned may be zero but, under present irrigation and drainage practices, commonly ranges from 10 to about 50 percent of the irrigation water applied. Since soluble salts are mostly excluded during plant uptake of water and thus are left behind in the soil during evaporation, there is a concentrating effect of the salts in the soil solution drained compared to the soil solution resulting from applied irrigation water. The water draining from the soils may contain such a high salt concentration that its further use is severely limited. In addition to the concentrating effect of evapotranspiration, the natural weathering of soils, chemical precipitation, solution and exchange of constituents in the soil solution with the solid soil particles further influences the concentration of the soil solution. Analysis of the total process is complicated by the time delay, amount of salt going into root zone storage, and in movement of constituents in the soil water from one part of the soil to another.

Previous research (King and Hanks, 1973) conducted by Utah State University indicates that there is considerable promise for exercising control of return flow quality by proper irrigation management. The basic premise underlying the research effort has been that the soil profile above the water table can be used as a temporary salt storage reservoir. Then, by proper management of irrigation, this salt may be released by leaching only when desired. Soil profile leaching is not necessary every year. Recent work (Bernstein and Francois, 1973) using greenhouse lysimeters supports the idea of salt storage and indicates that very small leaching fractions can be used over extended periods of time without adversely affecting yield of crops.

King and Hanks (1973) reported the development and testing of two independent mathematical models of water and salt movement through the soil with extraction of water by evapotranspiration. They concluded that the best model for irrigation management would probably result from a combination of the two. They recommended that further model development be done to reduce required computer time and eliminate the inherent numerical dispersion in the model affecting prediction of salt movement. They also suggested that time dependent root development and extraction pattern be incorporated into the model.

Other recommendations from the earlier work (King and Hanks, 1973) include suggested improvement of data collection procedures in the field for data to be used for model verification. The need for better definition of the soil solution electrical conductivity profile was cited. The earlier work also concluded that control of the quality of soil profile effluent will require precise control of water on the farm, particularly the depth and timing of irrigations. It was suggested that some of the costs of establishing adequate water management systems could result in benefits other than increased control of drainage water quality. Study of the economics of irrigation management were recommended. Using one of the models, King and Hanks (1973) tested the timing of irrigation as a management variable. With all other conditions the same, results showed that as the time interval between irrigations increases, the season totals of salt removed from the root zone, the salt remaining in the profile, and the amount of water required for leaching tend to become constant. However, the irrigation frequency has a significant effect upon when the salt is discharged during the season.

In the Ashley Valley of Utah, irrigation practices largely influence the quantity and quality of irrigation return flow. This is also true in many other areas of the Colorado River Basin and the United States. The research covered by this report included study of the degree of control of quantity and quality of return flow which is possible through management on the farm irrigation, drainage, and fertilizer application practices.

OBJECTIVES

The primary objectives of this research were to study various farm management practices related to irrigation and drainage and fertilizer use; and to determine their effects upon the quality and quantity of irrigation return flow.

The specific objectives were:

1. To monitor the movement of dissolved salts through the soil profile into the drainage water under different irrigation and/or drainage management practices.
2. To demonstrate the degree of control over the quality of the drainage water as influenced by these management practices.
3. To monitor the movements of nitrogen from applied commercial fertilizer and animal wastes through the soil profile and into the drainage water.
4. To evaluate the effects of various irrigation and/or drainage management practices upon these movements of nitrogen.
5. To develop management models which will describe these movements and allow for extrapolation of the results obtained from the Ashley Valley research farm to other conditions in other areas.

SECTION IV

METHODS

GENERAL

It is necessary to discuss some general aspects of the research farm and field data collection before focusing attention on the detailed studies of salt and nitrogen movement. Most of the field work reported herein was conducted on the Hullinger farm near Vernal, Utah. The location of the facilities existing on the farm immediately prior to initiation of this research were reported earlier (King and Hanks, 1973).

Drainage System Modification

The original tile drainage system consisted of six parallel drains originating at the north boundary of the farm and discharging separately into the Naples drain (a natural drainage channel). Drains 1 through 5 were spaced 61 m apart and drain 6 was 107 m west of drain 5.

In an effort to create more field plots underlain with a tile drain, the original system was modified during May and June 1972. A water-tight collector line was added in the east-west direction intersecting the drains about 70 m south of the north boundary of the farm. The collector was about 30 cm deeper than the drains. Water entered the collector only at the manholes into which the drains discharge. Everywhere else the collector was a water-tight pipe. Figure 1 shows the location of the collector drain with respect to the original tile drains.

The construction in 1972 also included the removal of a 6.4 m section of drain and gravel envelope from the six original tile drains to separate the drains into 3 sections. This separation was made about 140 m south of the north boundary of the farm. At the separation, each end of the remaining drain was plugged and soil material was compacted back into the trench excavated for removal of drain pipe and gravel envelope. Figure 1 shows the new drain configuration in which the new drains are designated such as 2N, 2M, and 2S meaning the north part of drain 2, the middle part of drain 2, and the south part of drain 2, respectively. Also shown in Figure 1 is a new drain 5A (5AN, 5AM, 5AS) installed in three separate parts corresponding to the modified drains and 61 m west of drain 5.

In the modified drainage system, all south drains discharged into the Naples drain through separate manholes as in the original system. The middle drains flowed to the north and discharged into manholes at the collector. The north drains flowed south to the collector manholes. The system allowed measurement of discharge and water quality of each drain separately at the manholes.

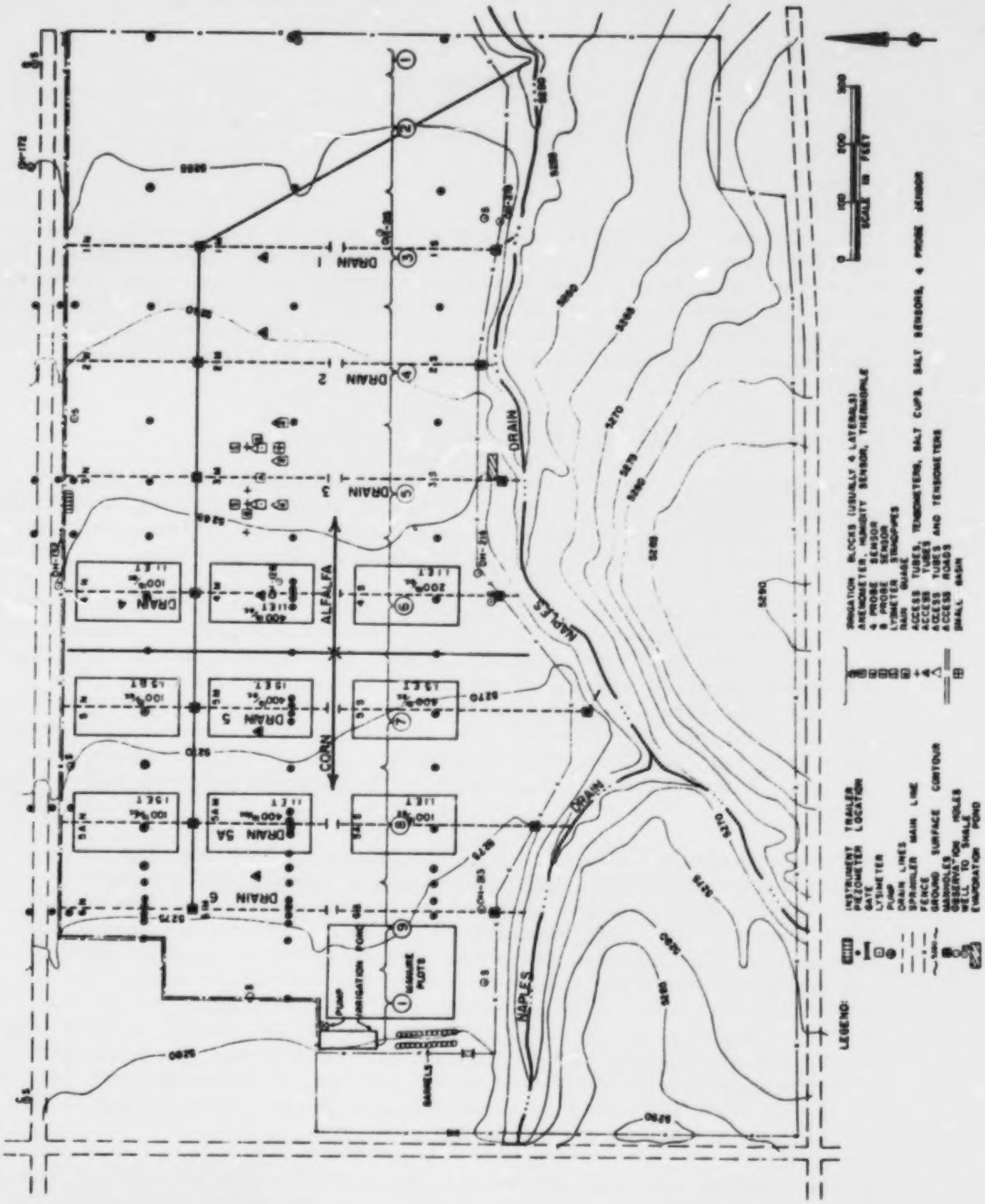

DRAIN 1
DRAIN 2
DRAIN 3
DRAIN 4
DRAIN 5
DRAIN 5A
DRAIN 6
ALFALFA
CORN
NAPLES DRAIN
NAPLES DRAIN
IRRIGATION POND
PUMP
MANURE PLOTS
BARRELS
5260
5270
5280
5290
SCALE IN FEET
0
100
200
300
LEGEND:
INSTRUMENT TRAILER LOCATION
PIEZOMETER
GATE
LYSIMETER
PUMP
DRAIN LINES
SPRINKLER MAIN LINE
FENCE
GROUND SURFACE CONTOUR
MANHOLES
OBSERVATION HOLES
WELL TO SHALE
EVAPORATION POND
IRRIGATION BLOCKS (USUALLY 4 LATERALS)
ANEMOMETER, HUMIDITY SENSOR, THERMOPILE
4 PROBE SENSOR
8 PROBE SENSOR
LYSIMETER STANDPIPES
RAIN GUAGE
ACCESS TUBES, TENSIOMETERS, SALT CUPS, SALT SENSORS, 4 PROBE SENSOR
ACCESS TUBES
ACCESS TUBES AND TENSIOMETERS
ACCESS ROADS
SMALL BASIN

Figure 1. Map of study area on the Hullinger farm near Vernal, Utah.

Irrigation Management Practices

Most of the work on some small field plots was designed to concentrate on the nitrogen movement rather than total dissolved solids (salinity). The salt movement was studied by separate field trials as explained in detail later. The irrigation and drainage management practices on the large plots over drains 3N,4N, 5N, 5AN, 6N, 3M, 4M, 5M, 5AM, 6M, 3S, 4S, 5AS, and 6S were designed with a dual purpose of studying both nitrogen and salt movement. The methods for collecting data which were common to both purposes is described under the heading "General Field Data."

The drainage management variable involved submergence of some of the drains to obtain anaerobic conditions in the drain pipe. Drains 5N and 5M were submerged by placing an elbow and short standpipe on the outlet end of each drain within the manhole at the collector. The overflow rim of the standpipe was about 25 cm above the invert of the drain pipe. Thus, the water table should have been at or above the top of the gravel envelope all along the drain in order for any water to be discharged from the drain. All other drains were free to flow unrestricted.

The irrigation management for 1972 is depicted on Figure 1. This involved two different water treatment levels, 1.1 and 1.5 times ET in which ET was the evapotranspiration of alfalfa as measured by two lysimeters near the center of the farm on either side of drain 3M. For 1973, irrigation water was added to the crop whenever soil moisture decreased to a predetermined level in the lysimeters.

General Field Data

The methods for collecting data which were common to both salt and nitrogen movement studies are reported here.

Evapotranspiration and Climate - Evapotranspiration was measured with hydraulic lysimeters. Global (solar) radiation was measured with an Eppley pyranometer and integrated electrically. Measurements of wet and dry bulb temperatures were made manually with a psychrometer. Some climatic data were taken from the local weather station at the airport which is about 0.8 km away. The data were analyzed in the same manner as outlined in the report for previous years (King and Hanks, 1973).

Drain Discharge - The discharge of the drains was obtained by measuring the time required to fill a container of known volume (bucket-stop watch method). These measurements were taken once a day (except weekends) for each drain which was flowing.

Drain Effluent EC - Each time drain discharge was measured a sample of the drain effluence was collected. Measurements of the electrical conductivity (EC) and the NO_3-N were made after the samples were brought into the laboratory. The EC was measured with a laboratory bridge and was reported as mmho/cm at 25 C.

Irrigation Water EC - The EC of the irrigation water was measured in the field with a portable conductivity meter which internally corrected all EC values to 25 C when a dial on the instrument was set by the operator to the water temperature of the sample. The measurements were made on samples withdrawn during each irrigation from the pond near the pump inlet by an automatic water sampler at a pre-set time interval.

Water Table Depth - Water table depth was measured weekly during the irrigation season at the piezometer locations shown on Figure 1. Details of the piezometers were explained earlier (King and Hanks, 1973). Since the elevation of the top of the piezometer was known, water table depth could be used to obtain water table elevation and hydraulic gradients in the groundwater.

SALT MOVEMENT

Field Studies

To accomplish the parts of objectives 1 and 5 relating to the field evaluation of the salt flow component of a model, it was necessary to conduct field tests. Earlier work (King and Hanks, 1973) indicated that the soil salinity status did not change as measured by salinity sensors and 4-probe sensors. Thus, Gupta (1972) artificially applied large amounts of salt to the soil surface in order to get measurable differences in the salinity status of the soil solution. Results from the models showed reasonable agreement with his field trial. Since there was some uncertainty about the field measurements and the model estimation of such an unnatural situation, the following additional field studies were conducted.

Field Trial 1 - In 1972 an evaporation pond (Figure 1) was constructed and filled with water early in the year. This was done to provide a source of salty water that would be similar chemically to the water used for normal irrigation but with a higher salt concentration. In previous studies dry salt was added to the soil surface. This technique resulted in a salt distribution in the soil that could not be completely explained other than by some indeterminate solution-dissolution function needed to establish boundary conditions for model evaluation. Since dry salt application was considered an abnormal situation, the evaporation pond method of supplying salty irrigation water was selected.

A new method of evaluating the electrical conductivity (EC) of the soil solution was also tested. This involved a field modification of the laboratory technique discussed by Gupta and Hanks (1972) where the four-probe EC was measured at 15-cm intervals up to 180 cm. According to the theory, this would allow for determination of the soil EC by

15-cm increments down to 180 cm. Measurements of soil water content were also needed to estimate the electrical conductivity of the soil solution for correction of the measurements. This was done with both neutron and gamma probes.

The apparatus for the 4-probe EC method is shown in Figure 2. The conductivity bridge was connected through a switch to the electrodes. The switch position selected the electrode spacing. By taking conductivity readings at different electrode spacings on the soil surface it is possible, according to Barnes (1954) to determine the resistivity as a function of depth. For example, the conductivity (mho) at the 15-30 cm depth is given as

$$K_{15-30} = K_{0-30} - K_{0-15}$$

the conductivity (mho/cm) can be given by

$$K(\text{mho/cm}) = \frac{K_{15-30}}{2\pi D}$$

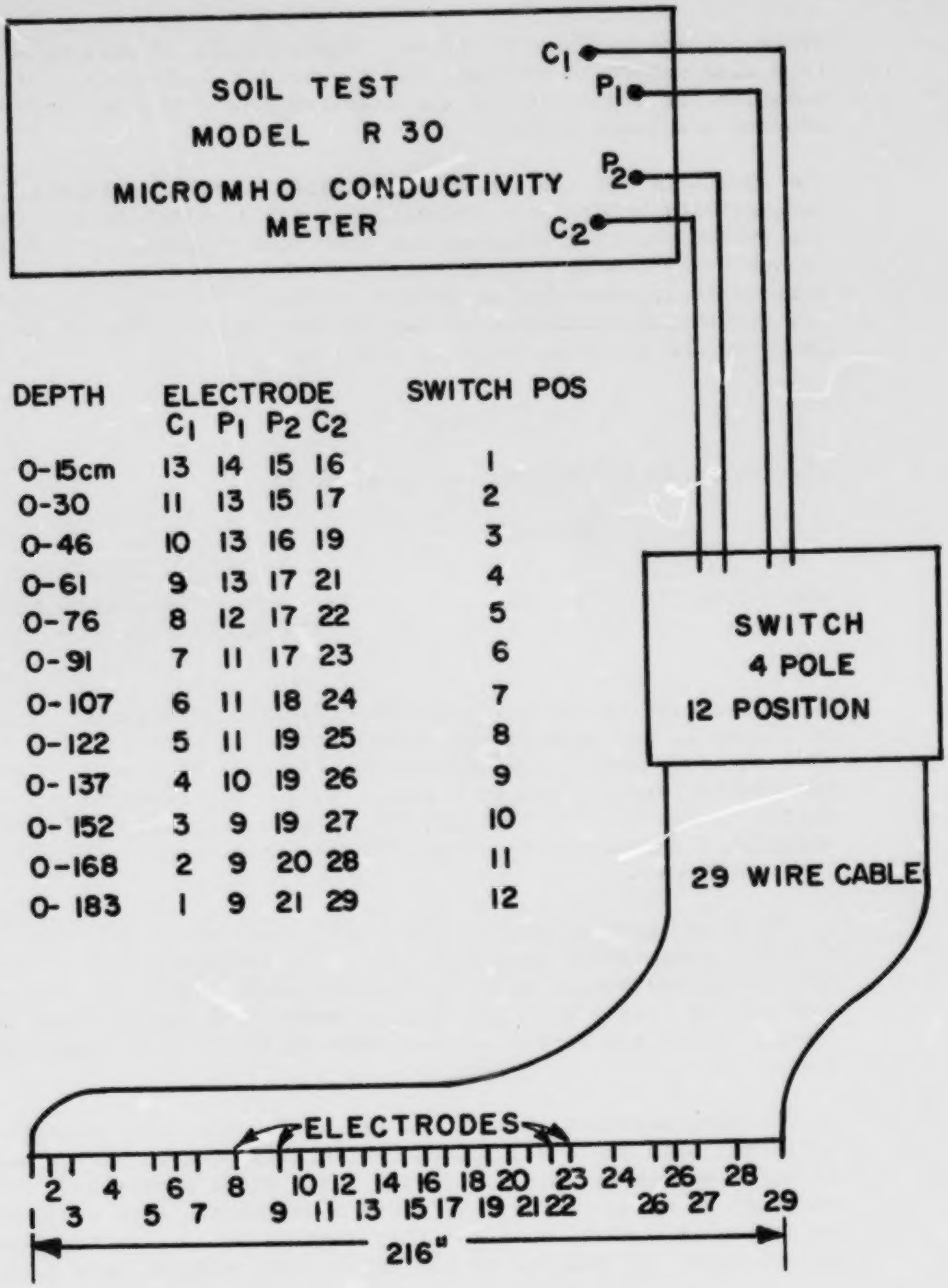
where D is the inner electrode spacing (cm). The conductivity bridge used was Model R30, Soiltest, Inc., 2204 Lee St. Evanston, Illinois 60202.

For evaluation of the salinity model, a site (designated "small basin" on Figure 1) was selected near neutron access tube B in plot 3M. In 1972 an area about 3 by 6 meters was enclosed by a soil "dike" constructed symmetrical to site B. Site B had tensiometer cups at depths of 15, 46, 76, 107, and 137 cm which were used to extract soil solution. Access tubes for neutron and gamma probe readings were also located there.

By the first part of August 1972, sufficient water had been evaporated from the evaporation pond that the EC of the water was 8.0 mmho/cm. This water was pumped onto the "small" basin August 9. The evaporation pond was re-filled with low quality water from Naples drain and the "small" basin was re-filled with this water (EC = 4.1 mmho/cm) on August 10.

Before each addition of water to the basin, the soil moisture content variation with depth was obtained with both neutron probes and the soil salinity status was monitored with the 4-probe apparatus. After each addition of saline water, the above measurements were repeated periodically. Also, soil solution samples were extracted from the porous cups. At the end of the trial, soil samples were taken.

Field Trial 2 - After the August 10 irrigation of the small basin, water from Naples drain was again pumped into the evaporation pond and allowed to concentrate until mid-September when another field test was made. On September 19 water from the evaporation pond (EC = 4.7 mmho/cm) was added to the small basin. Then on September 20 a high



SOIL TEST
MODEL R 30
MICROMHO CONDUCTIVITY
METER
C1
P1
P2
C2
SWITCH
4 POLE
12 POSITION
29 WIRE CABLE
ELECTRODES
2 4 6 8 10 12 14 16 18 20 23 24 26 28
1 3 5 7 9 11 13 15 17 19 21 22 26 27 29
216"

DEPTH	ELECTRODE C_1	P_1	P_2	C_2	SWITCH POS
0-15cm	13	14	15	16	1
0-30	11	13	15	17	2
0-46	10	13	16	19	3
0-61	9	13	17	21	4
0-76	8	12	17	22	5
0-91	7	11	17	23	6
0-107	6	11	18	24	7
0-122	5	11	19	25	8
0-137	4	10	19	26	9
0-152	3	9	19	27	10
0-168	2	9	20	28	11
0-183	1	9	21	29	12

Figure 2. Schematic diagram of 4-probe conductivity apparatus with associated switching arrangement.

quality water from the irrigation pond (EC = 1.1 mmho/cm) was added. For Field Trial 2 the procedures of data collection were the same as for Field Trial 1.

Field Trial 3 - Early in 1973 tests were made on plots near the irrigation pond in which water of various qualities were added to a ponded area. A much more intensive set of ceramic samplers was installed at various depths for soil solution sampling. Soil samples were taken before and after the tests. Four-probe readings were taken frequently throughout the tests. Corresponding neutron probe readings were made to obtain soil water contents. A portion of the irrigation water was pumped first into barrels where sufficient NaCl was added to bring the water up to an EC of about 10 mmho/cm. The sequence of water application was: (1) normal irrigation, (2) "salty" irrigation, (3) normal irrigation. This trial was conducted twice in 1973.

Measurement of pH, EC Ca, Mg, Na, SO_4, Cl and HCO_3 were made by the USU Soil Testing Laboratory on soil samples collected during the tests. Some of the water samples extracted from the ceramic cups were also analyzed for the above list. The rest of the water samples were analyzed for EC only. To estimate the amount of precipitated salts, measurements were also made on water extracted from the soil samples after dilution with distilled water at the ratio of 1/100 (soil/water).

Field Trial 4 - Additional field tests were made later in 1973 at the USU farm at Farmington, Utah, to assess the effect of a different soil on salt and water movements. Due to the difficulty of getting uniform water distribution under the previously used flooding techniques (Field Trials 1, 2, and 3), a new method was devised to apply water at Farmington. The water was applied using a large number of irrigation "drippers" arranged to wet the area without flooding. The infiltration rate of this soil was very low so some surface movement of water occurred but this was a small proportion of the total applied. Thus, the drip irrigation technique essentially solved the problem of uneven water distribution experienced in the flooding treatments. The sequence of water additions and the system of data collection was similar to Field Trial 3.

Field Trial 5 - An additional field trial at Logan, Utah was performed where another type of 4-probe conductivity tester called the "vertical 4-probe" was constructed and tested. This probe consisted of a 1.3 cm diameter fiberglass rod 122 cm long with a handle at one end and a sharp point on the other end. About 5 cm from the pointed end, a stainless steel ring slightly larger than the rod served as the bottom electrode. Three other similar electrodes at 5-cm spacing along the rod gave the 4-probe configuration. By inserting the rod into the soil at different depths, readings could be obtained of soil salinity in a vertical profile as a function of depth. This unit was designed to sample a small volume of soil. In practice it was found that the fiberglass rod was too flexible to push into the soil without first making a hole with a steel rod.

In the Logan tests a small basin about 1 m x 1 m was used. Water of various electrical conductivities (details in Section V, Results) was added in these tests. Water contents were measured with the neutron probe and EC was measured from soil samples by the 1:5 extract method. The vertical 4-probe equipment was also tested at Vernal during Field Trial 3.

The vertical 4-probe system has the disadvantage that the geometry of the electrical flow paths is not precisely known so it is impossible to convert the readings to mho/cm. The volume sampled is also uncertain. Tests in a water tank indicate that the volume sampled is a sphere of about 46 cm diameter. For the purpose of this field trial the relative readings given by the vertical 4-probe conductivity tests were considered sufficient for evaluation.

Laboratory Studies

Laboratory Trial 1 - This trial was run to determine in more detail the "buffering" or "salt source" characteristics of the soil from the Hullinger farm. Representative soil samples having various soil-water content ratios were prepared. The solution was extracted from the samples having soil water ratios ranging from 0.5 to 2.0. The electrical conductivity of the extract from each sample was measured and the relative amount of dissolved salts was determined.

Laboratory Trial 2 - A short-column leaching experiment was conducted in the laboratory to determine the order of magnitude of the relative change in concentration of the soil solution as a function of depth and time. The suitability of the 4-probe EC method for following the salinity of the soil solution in short columns during leaching was also evaluated in this trial.

The short soil column, consisting of three cylindrical segments each 5 cm high, was irrigated with "tap water" having an EC of 0.31 mmho/cm. Four electrodes were located in the cylinder wall along a horizontal circumference line 2.5 cm from the end of each segment. These four electrodes were connected to the conductivity bridge described earlier to measure the four-probe electrical conductivity, EC (4P). Measurements as functions of time were made of the quantities of water entering and leaving the column, the EC of the inflow and outflow, and EC (4P) of each segment.

Model Modifications

In order to accomplish objectives 1 and 5 it was considered necessary to modify the models described earlier (King and Hanks, 1973). It was concluded that the so-called simple model for water flow in the soil profile was not useful for further evaluation because of the inability of the model to account for upward flow. Thus it was decided to concentrate on modification of the more detailed model to be used as a water management tool to control the quantity and quality of irrigation return flow.

As reported by King and Hanks (1973) the detailed model predicted water flow quite well but was less satisfactory for predicting salt flow. Consequently a major effort was made to improve the salt flow computational methods. Further modification was also made of the model to allow for a developing root system for annual crops like corn. A further major modification involved an addition to the model of a procedure to predict plant growth as influenced by both water and salinity management. These modifications are outlined in the following discussion. The computer program printout is listed in Appendix A.

Salt Flow - The original model was limited in its ability to describe salt movement because diffusion and dispersion were not considered and because the numerical procedure used caused additional numerical dispersion (i.e., the results were influenced by the numerical techniques used). Consequently the anti-numerical dispersion modification is similar to that outlined by Bresler (1973) but was adjusted to account for varying depth increments (Bresler assumed equal depth increments). Further modification was made, after Bresler (1973), to include diffusion and dispersion. The general salt flow equation used was

$$\frac{\partial(C\theta)}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\partial C}{\partial z}\right) - \frac{\partial(qC)}{\partial z} \qquad [1]$$

where C is salt concentration, θ is volumetric water content, D is the combined diffusion and dispersion coefficient, q is mass flux of water, z is depth and t is time. This equation does not account for any precipitation or solution of salts within the profile.

The uncorrected numerical approximation of the left-hand side of equation [1], used was

$$\frac{\partial(C\theta)}{\partial t} = (C_i^{j+1}\theta_i^{j+1} - C_i^{j}\,\theta_i^{j})\,/\Delta t \qquad [2]$$

where i refers to the depth increment and j is the time increment and $\Delta t = t_{j+1} - t_j$.

The anti-numerical dispersion correction added to the right side of equation [2] was

$$\frac{\Delta t\ (\theta_i^{j+1} - \theta_i^{j})\ (q_{i+1/2}^{j+1/2} + q_{i-1/2}^{j+1/2})}{8\ (\theta_i^{2+1} + \theta_i^{2})}$$

$$\frac{q_{i+1/2}^{j+1/2}\ (C_i^{j+1/2} - C_{i+1}^{j+1/2})}{DLXB \cdot WD \cdot 2} - \frac{q_{i-1/2}^{j+1/2}\ (C_{i-1}^{j+1/2} - C_i^{j+1/2})}{DLXA \cdot WU \cdot 2} \qquad [3]$$

where

$DLXB = z_{i+1} - z_i$

$DLXA = z_i - z_{i-1}$

$$WD = \frac{\theta_i^{j+1/2} + \theta_{i+1}^{j+1/2}}{2}$$

$$WU = \frac{\theta_i^{2+1/2} + \theta_{i-1}^{2+1/2}}{2}$$

The first term in the right hand side of equation [1] accounts for diffusion and dispersion and has the following numerical approximation

$$\frac{\partial}{\partial z}\left(D\,\frac{\partial C}{\partial z}\right) = \frac{D_{i-1/2}^{j+1/2}\ (C_{i-1}^{j+1/2} - C_i^{j+1/2})}{DLXC\ .\ DLXA} - \frac{D_{-i+1/2}^{j+1/2}\ (C_i^{j+1/2} - C_{i+1/2}^{j+1/2})}{DLXC\ .\ CLXB} \qquad [4]$$

where

$DLXC = (z_{i+1} - z_{i-1})/2$

This numerical equation was used with no further modification. The value for D was chosen as follows

$$D_{i+1/2}^{j+1/2} = D_o\ A\exp(B\theta_{i+1/2}^{j+1/2}) + \lambda\ \left(\frac{q_{i+1/2}}{\theta_{i+1/2}}\right) \qquad [5]$$

The values used for the constants were (see Bresler, 1973)

$D_o = 0.05$

$A = 0.001$

$B = 10$

$\lambda = 0.4$

The numerical approximation for the mass flow term, uncorrected for numerical dispersion, was

$$\frac{\partial(qC)}{\partial z} = \frac{q_{i+1/2}\ C_i\ \ q_{i-1/2}\ C_{i-1}}{\mathrm{DLXC}} \qquad [6]$$

The following anti-numerical dispersion correction for equation [6] was (added to the right-hand side)

$$\frac{q_{i-1/2} \cdot (C_{i-1} - C_i)}{\mathrm{DLXC}} - \frac{q_{i+1/2} \cdot (C_i - C_{i+1})}{\mathrm{DLXC}} \qquad [7]$$

When the anti-numerical dispersion correction for the mass flow term, equation [7], was added to equation [6] the result turned out to be the same for upward or downward flow so no checks had to be made for flow direction.

The modified model in its present form still has two versions. The first version considers simple salt flow only. The second version includes the first but also has salt exchange, precipitation, solution, etc., included according to Gupta (1972) and Dutt et al, (1972).

During the modification of the model to incorporate the corrections for numerical dispersion (Bresler, 1973), test calculations were performed to evaluate the adequacy of these corrections for the salt flow part of the model. The earlier model suffered from numerical dispersion as evidenced by significant differences in results for different sizes of ΔX (depth) and Δt (time) increments. Table 1 shows the concentration profiles computed with the dispersion corrected model at two different times (t=16 and 240 hr) after an initially high salt concentration (t=0) in the surface layer was moved into the soil by irrigation. Note that the results for the version 1 of the model using two different Δt increments are reasonably close throughout the profile depth. The differences are well within the uncertainty that would be caused by the physical and chemical data used. It was concluded that the anti-numerical dispersion scheme used should give valid model predictions.

Table 1 also shows results of computations with the version 2 for one sequence of Δt increments. This version uses the numerical dispersion corrections and accounts for salt exchange, precipitation, solutions, etc. The results are not greatly different from the more simple version 1 of the model but do yield concentration peaks slightly lower in the profile that have lower concentrations.

Comparison of the computed salt distribution with the field measurements, as given by Gupta (1972), indicates that the computed salt concentration peaks given by both models are 10-20 cm too close to the soil surface. However, the field data measured are for large depth increments which lead to some uncertainty regarding the details of the

Table 1. INFLUENCE OF THE SIZE OF Δt INCREMENTS ON THE SALT CONCENTRATION PROFILE AT DIFFERENT TIMES.

Depth	C(t=0)	C(t = 16 hr)			C(t = 240 hr)		
		Δt=1 [a]	Δt=2	Δt=1	Δt=1	Δt=2	Δt=1
cm	meq/l	meq/l(1)	meq/l(1)	meq/l(2)	meq/l(1)	meq/l(1)	meq/l(2)
1	2704	11	11	10	71	68	35
3	53	11	11	10	65	63	28
5	54	10	9	11	65	64	37
8	54	12	7	20	69	69	52
12	54	54	48	50	84	85	70
16	54	124	125	95	105	106	86
20	54	162	169	130	123	126	105
25	56	141	145	133	136	139	120
30	55	101	102	111	134	137	122
35	56	74	73	86	120	122	117
40	55	61	60	68	103	103	108
45	55	56	56	58	75	75	94
55	59	58	58	55	66	66	76
70	57	57	57	57	66	65	65
85	56	56	56	56	57	57	59
100	56	56	56	56	57	57	58
115	53	53	53	53	55	55	54
135	50	50	50	50	52	52	52
155	50	50	50	50	50	50	51
165	53	53	53	53	53	53	53

[a] For Δt = 1 the time increments are similar throughout and Δt = 2 the time increments are twice as large.

(1) First version of model uses simple salt flow corrected for numerical dispersion.

(2) Second version of model uses corrections for numerical dispersion and accounts for salt exchange, precipitation, solution, etc.

exact location of the salt peak. The detailed model of Gupta (1972) does have the advantage that it predicts individual ion concentration but the accuracy was poor. Prediction of the distribution of total concentration of salts was more accurate than particular species distribution.

In view of the uncertainties discussed above, it was concluded that it would be reasonable to use the simple version of the model where exchange, etc., is not accounted for, to predict salt movement in the soil with occasional checks using the exchange version of the model. In situations where irrigation was with water having greatly different salt concentration than the previously used, model computations would be made using the exchange version (version 2) for comparison with calculations of the simple version (version 1).

Root Zone Extraction - This modification of the model was made to allow for seasonal changes in the rooting depth with time. The original model of Nimah and Hanks (1973a, 1973b) had a fixed depth and pattern of rooting. The root zone extraction modification allowed for simulations of annual crops, like corn or oats, to be used for the season where the root extraction patterns changed with time. Three input variables were required for the root profile to change with time up to root maturity. The input variables were

RDFSAV(I) = Root distribution function at maturity
RDFDAY = Number of days from the start until root maturity
RDFDEL = Number of time increments for root growth

For the first time increment, there were not roots in the soil profile. At the end of this time increment, a root distribution profile was calculated by scaling the mature root distribution profile to fit a smaller depth. This depth was calculated under the assumption that the root profile length versus time can be plotted as a sigmoid curve.

Yield Estimation - This modification was added to the model to estimate the effect of various irrigation management manipulations on yield. The salinity effects on yield were sensed only in the root extraction part of the model where water was taken up in response to a water potential gradient. The water potential gradient (WPG) was defined as

$$WPG_i = \frac{HROOT_i - (h_i + S_i)}{\Delta x} \qquad [8]$$

where $HROOT_i$ was the effective root water potential, h_i was the soil water matric potential and S_i was the soil solution osmotic potential (all at depth z_i). The distance of which the gradient applied, Δz, was assumed to be 1.0. The soil solution concentration was assumed to be directly proportional to S_i according to

$$S_i \text{ (millibars)} = 36\ C_i \text{(meq/1)}. \qquad [9]$$

The relative yield was assumed to be related to relative transpiration as

$$\frac{Y}{Y_p} = \frac{T}{T_p} \qquad [10]$$

where Y is the dry matter yield of a given crop for a given season, T is the transpiration for the same crop for the same season, Y_p is the potential yield for the same crop for the same season where soil water or salinity did not reduce yield and T_p is the potential transpiration for the same crop and season where soil water uptake was not limited and thus did not reduce yield. The values of T_p and T were summed up over the season to give one seasonal value for each quantity. T_p was also given by the input boundary conditions where transpiration was always equal to potential transpiration.

Input parameters were:

1. ESTART - the number of days from the start of computer simulation to seedling emergence.
2. ESTOP - the number of days from the start of computer simulation to maximum effective cover development
3. AK_1 = ratio of transpiration to evapotranspiration at maximum effective cover development.

These modifications were built into the computer program so that adjustments could be made from one crop to another through input conditions. Otherwise the input data were the same as given by Nimah and Hanks (1973a, 1973b).

This yield estimation modification, including the background of equation [10], is very complicated as discussed by Hanks (1974). However, it seems to give good results.

Transpiration/Evapotranspiration - This modification was used to allow for variations in the relative proportion of T_p/ET_p over the course of the season. The model of Nimah and Hanks (1973b) allowed for this proportion to change but because alfalfa was the crop tested T_p/ET_p was assumed to be constant of 0.9 throughout.

It was assumed that the ratio of transpiration to evapotranspiration versus time for annual crops fitted a sigmoid curve. The sigmoid curve was used to define the relationship between the time of seedling emergence and the time of no further change in the T_p/ET_p ratio. Knowing maximum T_p/ET_p at a given time, transpiration could be calculated for any time.

In the event of soil-water constraints on evaporation, a higher proportion of water will be transpired to meet environmental demands.

When actual evaporation, E, fell short of potential, transpiration was adjusted upward to make up the energy balance difference according to the following equation

$$T_p = (ET_p - E_p) \cdot [1 + (\frac{1.0}{AK_1} - 1) \cdot \frac{E_p - E}{E_p}] \qquad [11]$$

If T_p, computed from equation [11] plus E was greater than ET_p, then T_p was taken to be equal to ET minus E.

Daily Evapotranspiration - This modification was made to account for the normal fluctuation in ET demand during the daylight hours with essentially zero ET demand at night. The original model assumed average ET conditions to be constant over periods of several days. In the absence of detailed information on this variation, a sinusoidal pattern was assumed. The variation of evapotranspiration rate was assumed to start at zero at 0800 hrs, reach a maximum at 1400 hrs, and return to zero at 2000 hrs. Between 2000 hrs and 0800 hrs the next day, evapotranspiration was assumed to be zero. The field input evapotranspiration rates were averages over a given time period so the program took these averages and reapportioned them for each time increment of the daily cycle.

NITROGEN MOVEMENT

Commercial Fertilizer Plots

To study the movement of commercial nitrogen fertilizer in response to water management, crops and plots were established in 1972 as shown in Table 2 (See also Figure 1). The "high" water table denotes the submergence of drains 5N and 5M as explained earlier under the heading "Irrigation Management Practices". The "normal" water table indicates that no restriction was placed on drain discharge. (See Section IV, Results, for discussion of the actual water table depths which occurred.) The area of the plots receiving uniform application of $Ca(NO_3)_2$ fertilizer was centered over the drains as indicated by the rectangles shown in Figure 1. The size of each treated area was 30.5 by 54.9 m (about 0.17 hectare). Evapotranspiration (ET) was measured by the lysimeters in plot 3M and was used as a basis for irrigating the plots at about 1.1 and 1.5 times ET. The details of the times of irrigation and EC (electrical conductivity) of the irrigation water are given in Appendix B. The rate of water application by the sprinkler system was 0.64 cm/hr.

This experiment was repeated in 1973 with some modifications. The nitrogen fertilization was the same as 1972 except that the fertilizer used was NH_4NO_3. This was done because of cost (a factor of two) and

Table 2. COMMERCIAL FERTILIZER NITROGEN TREATMENTS ESTABLISHED IN 1972 ON THE HULLINGER FARM.

Plot	Crop	Water Table	Nitrogen Level[a]	Irrigation
3N	Alfalfa	Normal	0	1.1 ET
3M	"	"	0	"
3S	"	"	0	"
4N	"	"	121 Kg/ha (100 lbs/a)	"
4M	"	"	484 Kg/ha (400 lbs/a)	"
4S	"	"	242 Kg/ha (220 lbs/a)	"
5N	Corn	High	121 Kg/ha (100 lbs/a)	1.5 ET
5M	"	"	484 Kg/ha (400 lbs/a)	"
5S	"	Normal	484 Kg/ha (400 lbs/a)	"
5AN	"	"	121 Kg/ha (100 lbs/a)	"
5AM	"	"	484 Kg/ha (400 lbs/a)	1.1 ET
5AS	"	"	121 Kg/ha (100 lbs/a)	"
6N	"	"	0	"
6M	"	"	0	"
6S	"	"	0	"

[a] Elemental N applied as $Ca(NO_3)_2$.

because the 1972 results showed little nitrate moving through the soil in the alfalfa plots. Since the fertilizer had to be broadcast and not disced in the alfalfa, as it was in the corn, it was originally thought that a nitrate fertilizer, $Ca(NO_3)_2$, was necessary.

The irrigation water applications were not maintained at as high a level in 1973 as they were in 1972. The irrigation on the corn was decreased drastically in 1973, compared to 1972, because irrigation on the corn was applied when the actual soil water levels decreased to a predetermined value.

Because of the delay caused by construction of the drainage system modification, it was necessary to delay the 1972 planting of corn until late June. Just prior to planting the corn, the ground was plowed out of alfalfa after the first crop was cut. Corn was planted on May 15, 1973.

Two porous ceramic samplers (Soil Moisture Equipment Co., Santa Barbara, California approximately 4 cm, 1-5/8 in. diameter) were installed to a depth of about 106 cm in northeast and southwest quarter of each plot in 1972. In 1973 two samplers were installed at each location used in 1972 (four samplers per plot) with one at 76 cm and the other at 106 cm depth. Samples were collected at periodic intervals throughout the season generally a day or two after irrigation. For sampling, suction was applied to the sampler with a hand pump. The sample was collected several hours later by applying suction to the sampling bottle which was connected to a small tube pushed into the water that had collected in the bottom of the sampler.

Manure Plots

Forty-eight plots were laid out near the irrigation pond for the dairy manure studies. The detail of these plots are shown in Figure 3. Plots were 6.1 by 12.2 m where crops were grown and 6.1 by 6.1 m for the bare treatments. Rates of manure application in 1972 were 0, 54, 108, and 216 metric tons per hectare (mt/ha) calculated as a dry weight equivalent (0, 25, 50, and 100 t/a). Irrigation was by sprinkler. The manure was plowed in immediately after application of the plots. As shown by Figure 3, half of the cropped plots were planted to corn and half to sudan grass at the end of June, 1972.

In 1973 all of the cropped plots were planted to corn on May 15. Prior to planting, the plots that had been in sudan grass the previous year were retreated with the same amounts of dairy manure as shown in Figure 3.

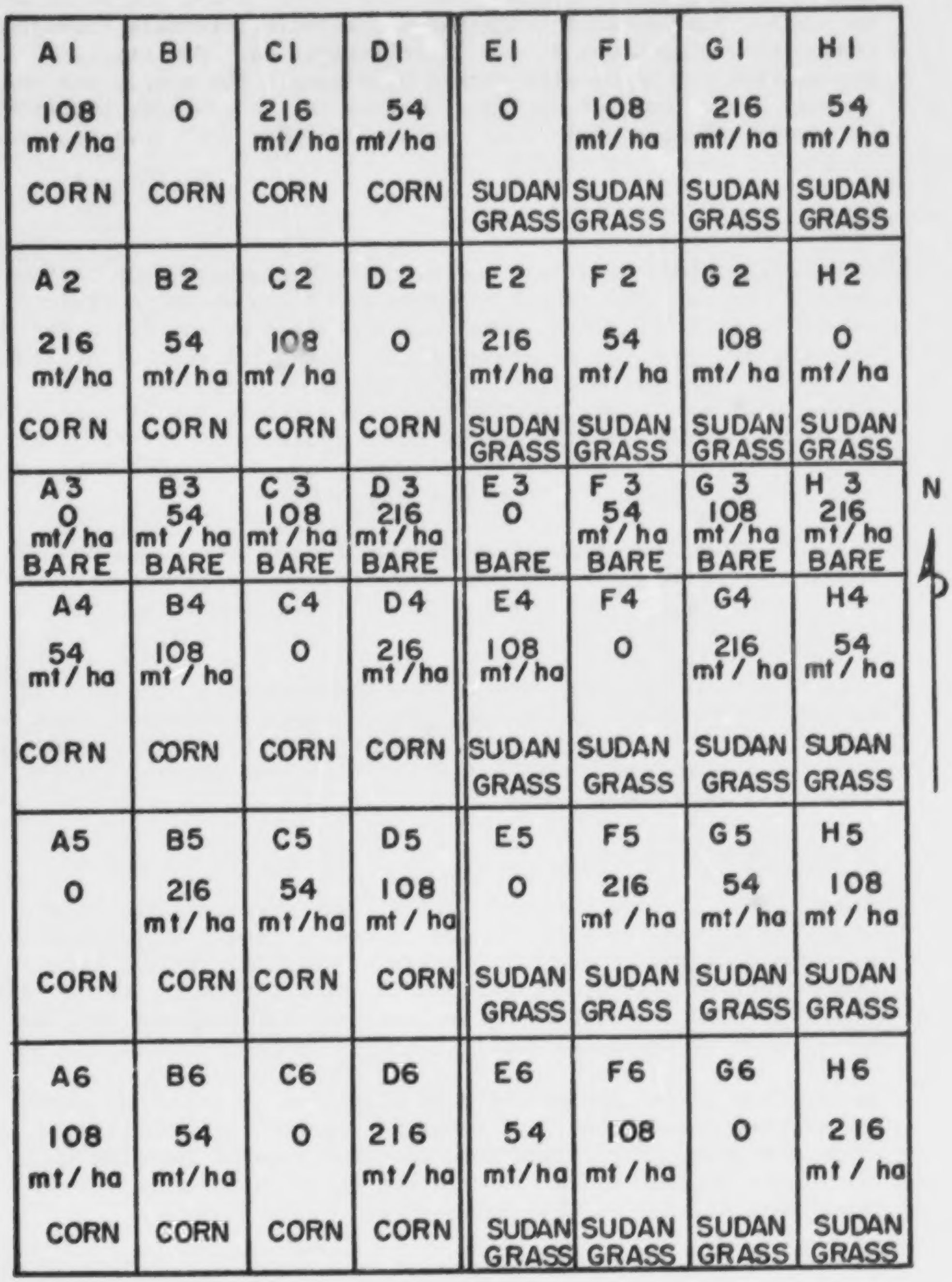
Ceramic soil water solution samplers were installed in the middle of each plot to a depth of 106 cm. These samplers were also used as access tubes for measuring soil water content with the neutron probe. Sampling was accomplished in a manner described earlier for the commercial fertilizer plots.

Barrel Lysimeters

In an effort to have a closed system where uncertainties regarding upward water flow were eliminated, barrel lysimeters were installed as shown in Figure 1 near the manure plots. The barrels received the same amount of irrigation water as the manure plots. Ceramic samplers were installed in the barrels for solution sampling and soil moisture measurement as described earlier.

Twenty-four barrel lysimeters were installed in 1972. An essentially undisturbed core of soil was removed from the field and placed in a 55-gallon drum. The filled drum was then lowered into the hole. Treatments applied to the barrels are shown in Table 3. These treatments were applied in 1972 only.

Barrels 5, 6, 7 and 8 were scheduled to receive a high rate of water application throughout the season in 1972 while the remaining barrels were scheduled to receive a normal application of irrigation water.



A1 108 mt/ha CORN	B1 0 CORN	C1 216 mt/ha CORN	D1 54 mt/ha CORN	E1 0 SUDAN GRASS	F1 108 mt/ha SUDAN GRASS	G1 216 mt/ha SUDAN GRASS	H1 54 mt/ha SUDAN GRASS
A2 216 mt/ha CORN	B2 54 mt/ha CORN	C2 108 mt/ha CORN	D2 0 CORN	E2 216 mt/ha SUDAN GRASS	F2 54 mt/ha SUDAN GRASS	G2 108 mt/ha SUDAN GRASS	H2 0 mt/ha SUDAN GRASS
A3 0 mt/ha BARE	B3 54 mt/ha BARE	C3 108 mt/ha BARE	D3 216 mt/ha BARE	E3 0 BARE	F3 54 mt/ha BARE	G3 108 mt/ha BARE	H3 216 mt/ha BARE
A4 54 mt/ha CORN	B4 108 mt/ha CORN	C4 0 CORN	D4 216 mt/ha CORN	E4 108 mt/ha SUDAN GRASS	F4 0 SUDAN GRASS	G4 216 mt/ha SUDAN GRASS	H4 54 mt/ha SUDAN GRASS
A5 0 CORN	B5 216 mt/ha CORN	C5 54 mt/ha CORN	D5 108 mt/ha CORN	E5 0 SUDAN GRASS	F5 216 mt/ha SUDAN GRASS	G5 54 mt/ha SUDAN GRASS	H5 108 mt/ha SUDAN GRASS
A6 108 mt/ha CORN	B6 54 mt/ha CORN	C6 0 CORN	D6 216 mt/ha CORN	E6 54 mt/ha SUDAN GRASS	F6 108 mt/ha SUDAN GRASS	G6 0 SUDAN GRASS	H6 216 mt/ha SUDAN GRASS

Figure 3. Manure plot layout on Hullinger farm.

Table 3. FERTILIZER TREATMENTS APPLIED TO BARREL LYSIMETERS IN 1972.

Barrel No.	Treatments
1, 4	440 Kg/ha N as $Ca(NO_3)_2$
2, 3	216 mt/ha manure
5, 8	110 kg/ha N as $Ca(NO_3)_2$
6, 7	440 kg/ha N as $Ca(NO_3)_2$
9, 12	440 kg/ha N as $Ca(NO_3)_2$
10, 11	110 kg/ha N as $Ca(NO_3)_2$
13, 19, 22	108 mt/ha manure
16, 20, 23	No application - Check
15, 18, 24	54 mt/ha manure
14, 17, 21	216 mt/ha manure

Barrels 1, 2, 3, and 4 had drain cans installed so that any free water existing at the bottom of the barrel would drain out of the soil into the drain can from which a sample could be removed. In the other barrels, free water would remain in the soil. However, the amount of water applied in 1972 was so great that all of the barrels without drains were waterlogged throughout most of the year. Consequently in 1973 drains were installed in all of the barrels and no water-logging occurred. Corn was planted in the barrels in both years at the same time the manure plots were planted.

Sample Analysis

Soil sampling of the manure and nitrogen fertilizer plots was done in the fall and spring. These samples were put in a room at 0° C until the chemical analyses for nitrates and EC could be made. EC was determined on the saturated paste extract before nitrate analysis.

Nitrate content was determined for soil, plant, and water samples using the phenoldisulfonic acid method (Bremner, 1965) and modified to eliminate chloride interference by using 0.02 N copper sulfate--0.002 N silver sulfate extract-in-solution in a 5/1 ratio of solution to soil. Conductivity was determined with a pipette conductivity cell. Total N was determined by micro Kjeldahl.

Vegetation samples were collected, dried and analyzed by the same procedures used for soils. Only leaves near the ear were selected for corn samples.

SECTION V

RESULTS AND DISCUSSION

GENERAL

Results common to both salt and nitrogen movement studies are given before results specific to each.

Evapotranspiration and Climate

Lysimeter evapotranspiration and climatic data are shown in detail in Appendix B (Tables B-1 and B-2). The data indicate that the ET from the lysimeters was about 62 cm in 1972 (from June 24 through September). Sufficient data was collected so that the potential evaporation from a free water surface could be computed by the Penman equation with two modifications described by Wright and Jensen (1972). Figure 4 shows that the lysimeter cumulative evapotranspiration is about 19 cm greater than the potential evaporation as computed by the Penman equation. There was very little difference between the two modifications of the Penman equation. Thus it is apparent that the potential evaporation as computed by the Penman equation does not have the expected simple relation to the measured evapotranspiration. It was expected that the ratio of measured ET to Penman E would vary from about 0.8 to 1.1 during the season. This result is similar to that measured in 1971 [King and Hanks, (1973)].

Irrigation

Details of irrigations applied to the Hullinger Farm for 1972 and 1973 are given in Appendix B (Tables B-3 and B-4). Also shown are the date and the depth and electrical conductivity of water applied for each irrigation.

The irrigation data are summarized in Table 4. While the average EC values of Table 4 are grouped around 1.0 mmho/cm the range of values for individual irrigations was 0.8 to 1.6 mmho/cm for 1972 and 0.6 to 1.5 mmho/cm for 1973.

Drainage Discharge

The discharge of water from each tile drain was measured daily over a short time interval (essentially an instantaneous measurement). All discharge measurements are reported in Appendix B (Tables E-5 and B-6). The drain discharge data are summarized as cumulative drainage in Table 5.

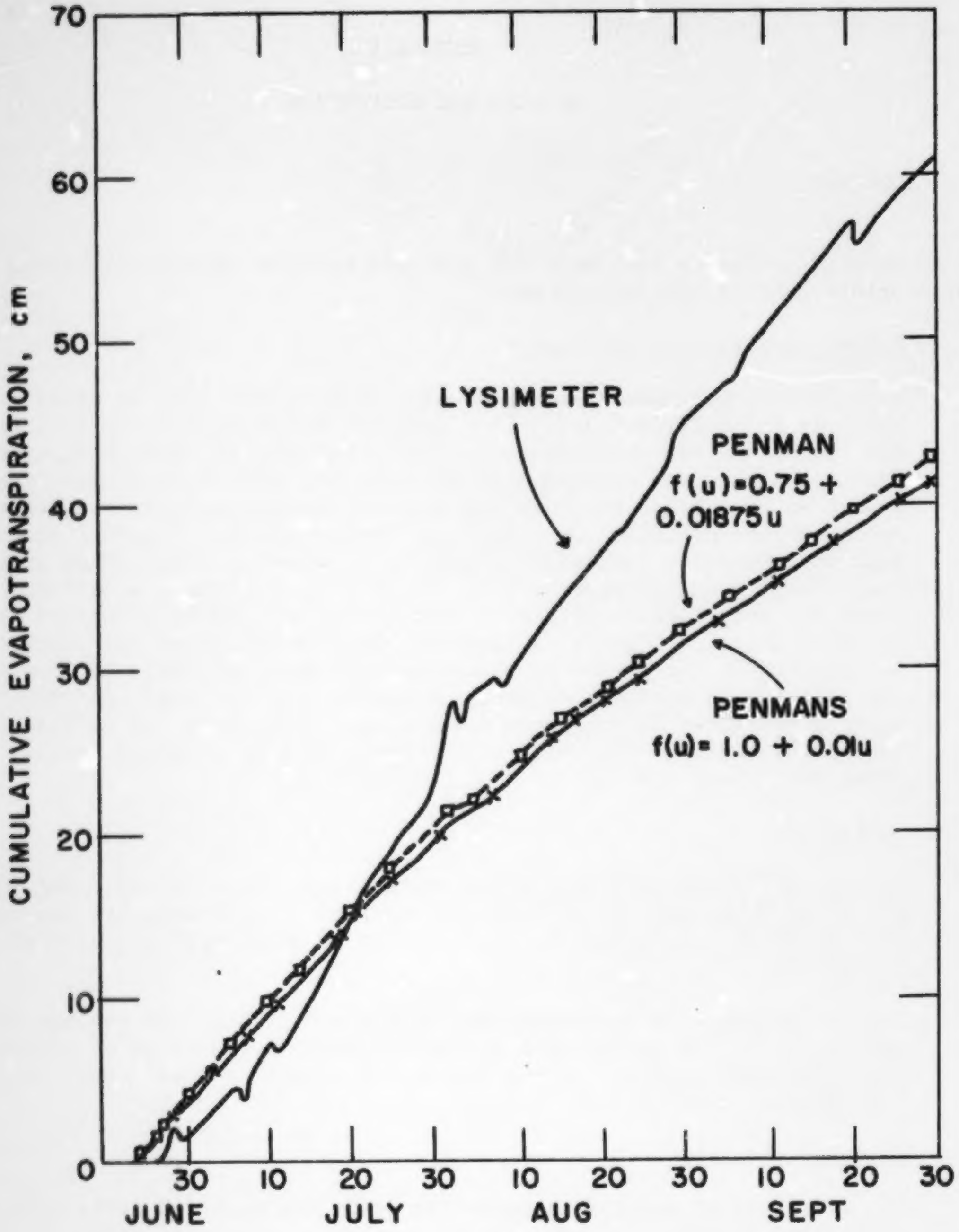


Figure 4. Cumulative evapotranspiration measured by lysimeters compared with potential evaporation computed with Penman's equation for 1972.

Table 4. TOTAL IRRIGATION WATER APPLIED, NUMBER OF IRRIGATIONS, AND AVERAGE EC OF IRRIGATION WATER ON HULLINGER FARM.

Block [a]	Plot [a]	Crop	Total Water Applied (cm)	Number of Irrigations	Average [b] EC (mmho/cm)
		-1972-			
1	--	Corn	68.8	12	1.2
1	--	Alfalfa	55.4	8	1.1
2	--	Alfalfa	89.3	11	1.1
3	1N, 1M, 1S	Alfalfa	73.3	19	1.1
4	2N, 2M, 2S	Alfalfa	66.9	13	1.1
5	3N, 3M, 3S	Alfalfa	63.9	9	1.0
6	4N, 4M, 4S	Alfalfa	65.3	12	0.9
7	5N, 5M, 5S	Corn	83.1	15	1.1
8	5AN	Corn	87.2	14	1.1
8	5AM, 5AS	Corn	72.3	14	1.1
9	6N, 6M, 6S	Corn and Sudan Grass	74.1	14	1.1
		-1973-			
1	--	Corn	35.2	8	1.0
1	--	Alfalfa	34.5	6	0.9
2	--	Alfalfa	56.4	7	1.0
3	1N	Alfalfa	83.2	10	1.0
3	1M, 1S	Alfalfa	52.8	8	1.0
4	2N	Alfalfa	84.5	9	1.0
4	2M, 2S	Alfalfa	54.1	7	1.0
5	3N	Alfalfa	83.6	9	1.1
5	3M, 3S	Alfalfa	53.2	7	1.1
6	4N, 4M, 4S	Alfalfa	53.0	7	1.0
7	5N, 5M, 5S	Corn	30.9	6	0.9
8	5AN, 5AM, 5AS	Corn	31.1	6	0.9
9 [c]	6N, 6M, 6S	Corn	32.6	6	1.0
9 [d]	--	Corn	35.2	8	1.0

[a] The block and plot designations are given in Figure 1.

[b] EC of each irrigation weighted by amount of water applied. Irrigations for which EC data were not available were ignored in computing average EC.

[c] East part.

[d] West part.

Table 5. CUMULATIVE DRAINAGE IN 1972 (STARTING 6-28) AND 1973 (STARTING 6-18).

(m^3)

Plot[a]	Date						Depth[b] cm
	6-30	7-15	7-30	8-15	8-30	9-15	
				-1972-			
3N	21	38	38	178	200	229	5
4N	32	246	492	1005	1280	1576	34
4M	4	21	94	375	571	761	16
4S	0	0	0	35	46	46	1
5N	26	670	1199	1864	2315	2667	57
5M	5	130	276	492	636	696	15
5S	0	0	40	264	300	300	6
5AN	3	114	227	364	438	477	10
5AM	1	60	145	261	303	333	7
5AS	0	0	42	140	140	140	3
6N	1	285	590	790	1030	1081	23
6M	0	73	228	319	348	354	8
6S	0	0	18	44	44	44	1
				-1973-			
1N	72	72	261	264	294	363	8
1M	7	8	8	9	9	9	0
2N	185	217	546	577	729	1092	24
2M	24	25	25	25	26	26	1
3N	424	633	1446	1864	2707	3714	80
3M	34	34	35	47	77	112	2
4N	363	500	1325	1997	3243	4318	93
4M	216	263	633	937	1434	1846	40
5N	365	585	1534	2375	3701	4646	100
5M	41	43	168	268	435	492	11
5AN	48	80	196	318	617	627	13
5AM	27	48	116	157	231	270	6
6N	228	386	1004	1575	2815	3367	72
6M	34	68	220	305	575	657	14

[a] Plots not included in list, had no discharge from drain.

[b] Cumulative on 9-15 assuming a plot size of 76 x 61 m (250 x 200 feet).

The data of Table 5 show that by July 1972 some of the south drains had discharged water while in 1973 none of the south drains had had any discharge. These differences in discharge from the south drains can be explained by the differences in irrigation water applied. Table 4 shows that the plots overlying all south drains received more water in 1972 than in 1973. In 1972, plots 5S, 5AS, and 6S received more than twice the irrigation water applied to these plots in 1973.

All north drains had more discharge in 1973 than in 1972 as did the middle drains except 5M and 5AM. Even for drains 1N, 2N, and 3N the extra irrigations on June 19 and June 25, 1973 cannot explain the greater discharge because these effects should have been dissipated within a week or two, but the discharge of drains 1N, 2N, and 3N increased significantly on into August and September. Except for plots 1N, 2N, and 3N, all plots received more irrigation water in 1972 than 1973. Note also that drain 5N discharged almost twice the water in 1973 as in 1972 and the 1973 discharge for drain 6N was about 3 times the 1972 discharge (Table 5). The 1972 irrigation water applied to plots 5N and 6N was more than twice the 1973 applications. For 1973, drain 5N discharged about 3 times the water applied as irrigation to plot 5N (assuming a plot size of 76 x 61 m) and drain 6N discharged more than twice the water applied.

The above discussion leads to the conclusion that drain discharge was significantly affected by factors other than water management practices on the farm itself. This conclusion is also supported by an analysis of water table requirements.

Much of the water discharged by the drains must have originated outside the farm boundary, which will be discussed later. Any control over salt movement in the root zone may be masked by groundwater flow conditions unless the control area is large enough to influence the groundwater basin. Thus it is apparent that a single farmer or small group of farmers cannot hope to significantly influence the quality of irrigation return flow. Control programs must be large enough to encompass hydrologic units.

Water Table Depth

Water table depth was measured at approximately weekly intervals at all the piezometer locations shown in Figure 1. Results from selected piezometers are included in this report. Locations of these piezometers are given in Table 6. The locations identified with numbers 1 through 14 are included mainly to determine groundwater hydraulic head gradients which are discussed in a following section under the heading "Groundwater Movements." The piezometers numbered 15 through 28 (Table 6) are included to show the water table depths under field plots. Table 7 gives the piezometer identification number, the field plot and the average water table depths for 1972 and 1973. In all cases the average depth to water table was less in

Table 6. PIEZOMETER IDENTIFICATION NUMBER.

Location[a]	Ident. No.	Location[a]	Ident. No.	Location[a]	Ident. No.
1W100N50	1	5AE25-20	11	4W5-400	20
1W100N4	2	6W5N50	12	5W5-400	21
1W100-20	3	6W5N12	13	5AW5-400	22
3W5N47	4	6W5-20	14	6W5-400	23
3W5N4	5	3W5-150	15	4W5-650	24
3W5-20	6	4W5-150	16	5W5-655	25
3W100N43	7	5W5-150	17	5AW5-650	26
3W100-20	8	5AW5-150	18	6W5-650	27
5AE25N50	9	6W5-150	19	6W149-400	28
5AE25N12	10				

[a] The location of piezometer shown on Figure 1 is designated by a coordinate system referenced to the drains and to the north boundary fence of the form. Thus, "1W100N50" means 100 ft. west of drain 1 and 50 ft. north of the fence. For locations south of the fence, "-" is used in place of "N".

1973 than in 1972. While these piezometers are only 1.5 m from the drains, studies of drain performance on the Hullinger farm (Sabti, 1974) show that most of the water table drop occurs closer to the drains and that piezometers 1.5 m from the drains give essentially the same water table depth as those farther from the drains. The water table tends toward a plane between drains with most of the lowering of the water table occurring very close to the drains. All measurements of water table depth for the selected piezometers (Table 6) are shown in Appendix B (Tables B-7 and B-8).

Groundwater Movements

As discussed above, much of the water discharged by the drains came from groundwater moving from outside the boundaries of the Hullinger farm. The water table depth from piezometers 1 through 14 (Table 6) may be used to determine the tendency for groundwater encroachment from the north. Groups of these piezometers form north-south lines over which the hydraulic head gradients can be calculated. Five north-south lines are represented by the following piezometer groups: 1, 2, 3; 4, 5, 6; 7, 8; 9, 10, 11; 12, 13, 14. The water table depth

Table 7. AVERAGE WATER TABLE DEPTH DURING IRRIGATION SEASON UNDER FIELD PLOTS ON THE HULLINGER FARM.

Identification No.	Plot	Average Water Table Depth(m) 1972	1973
15	3N	1.59	1.43
16	4N	1.18	1.13
17	5N	1.08	1.03
18	5AN	1.31	1.23
19	6N	1.58	1.48
20	4M	1.36	1.30
21	5M	1.34	1.30
22	5AM	1.32	1.24
23	6M	1.47	1.39
24	4S	1.87	1.83
25	5S	1.78	1.77
26	5AS	1.80	1.78
27	6S[a]	2.16	2.07
28	Manure Plots[a]	1.66	1.47

[a] Piezometers 27 and 28 may be used to estimate the water table depth beneath the manure plots.

measurements were used to calculate water table elevation above mean sea level (Tables B-7 and B-8). A survey of water table elevation for these groups of piezometers shows that whenever there were differences, the gradient was such that the groundwater flowed toward the south. That there is a southerly component to groundwater flow under the plots is indicated by the water table elevations, for instance for piezometers 16, 20, and 24, the main ground water flow is from west to east.

SALT MOVEMENT

Field Studies

Irrigation Management - Irrigation of the large plots during 1972 was scheduled as indicated in Figure 1 where ET denotes the evapotranspiration of alfalfa as measured by the lysimeters in plot 3M. These irrigation amounts were scheduled to insure that nitrogen would move downward through the soil. Earlier experience (King and Hanks, 1973) on the Hullinger farm indicated that significant upward flow of water from the water table to the root zone could occur. The irrigation for 1972 was planned in an attempt to minimize this effect. In 1973 the corn was irrigated whenever the soil moisture decreased to a predetermined level resulting in much lower total water application than in 1972.

Effects of irrigation management on salt movement was studied by EC measurements of drain water and water samples collected from ceramic cups placed in the soil above the water table. Each time the drain discharge was measured, a sample of the effluent was collected and EC measurements made. Electrical conductivity (EC) of these samples is given in Appendix B (Tables B-9 and B-10). Using the EC data of Tables B-9 and B-10 and the drain discharge data of Tables B-5 and B-6, the cumulative mass of salt removed by the drains was calculated and is presented in Table 8. Table 8 shows that although the average EC for any drain was essentially the same for 1972 and 1973, the total salt discharged was greater for 1973. Since the EC of irrigation water was also essentially the same for these two years, the greater salt discharge was caused directly by greater drain flow.

In general, the high EC values of drain effluent are associated with drains having low flows. The average EC (Table 8) increases progressively from north to south (for example, plots 6N, 6M, and 6S for 1972). Thus, evidence exists indicating salt storage in zones above the water table. This storage has probably been going on for a long time and is probably not directly a result of irrigation management practiced since research began on the Hullinger farm. Note from Table 7 that water table depths also increase from north to south. This is the result of natural groundwater hydrology for this area. In 1970 and 1971, before the drains were divided, the single drain 3 was observed to flow only once as a result of the discharge of water directly over the drain from a disconnected irrigation pipe. In 1972 and 1973, after drain division, drain 3S never flowed while drain 3N flowed significantly. Thus it is apparent in 1970 and 1971, water entered the north part of drain 3 and seeped back into the groundwater in the south part before reaching the measuring manhole.

Table 8. CUMULATIVE SALT FLOW FROM THE DRAINS IN 1972 (STARTING 6-28) AND 1973 (STARTING 6-18).

(kg)

Plot	Date						EC AVE mmho/cm
	6-30	7-15	7-30	8-15	8-30	9-15	
			-1972-				
3N	27	47	47	220	254	300	2.1
4N	28	210	428	904	1200	1498	1.5
4M	5	30	120	488	773	1056	2.2
4S	0	0	0	60	80	80	2.7
5N	26	602	1129	1838	2410	2872	1.8
5M	5	126	287	550	775	867	2.0
5S	0	0	38	215	239	239	2.2
5AN	3	100	187	282	327	351	2.3
5AM	1	46	111	191	217	235	2.3
5AS	0	0	54	185	184	184	2.2
6N	2	353	675	855	1042	1081	1.8
6M	0	73	279	394	443	453	2.2
6S	0	0	11	72	72	72	2.9
			-1973-				
1N	111	112	403	449	455	567	2.5
1M	13	14	15	15	16	17	3.6
2N	295	348	821	863	1087	1603	2.4
2M	39	39	40	41	41	42	3.4
3N	512	769	1711	2155	3111	4267	1.8
3M	42	42	43	61	103	154	2.3
4N	400	544	1444	2128	3428	4556	1.7
4M	303	374	920	1348	2046	2642	2.2
5N	460	732	1885	2771	4162	5167	1.8
5M	61	64	248	372	588	657	2.1
5AN	69	115	271	425	652	780	2.0
5AM	47	85	194	257	366	420	2.5
6N	248	423	1102	1704	3001	3623	1.7
6M	55	106	327	445	795	899	2.2

Tables B-9 and B-10 show that the EC of drain effluent ranged from 1.1 to 3.7 mmho/cm. For drains for which 5 or more samples were taken, i.e., drains observed to flow on 5 or more days, the range was 1.1 to 3.3 mmho/cm.

Table B-9 shows a general increase in EC as the 1972 season progressed. For 1973, this trend was reversed as shown in Table B-10. This trend could have been influenced by differences in amounts of irrigation water applied to the Hullinger farm for these two seasons. However, such effects are probably masked by the groundwater movement from outside farm boundaries.

Electrical conductivity measurements on water samples withdrawn from the ceramic cups in the soil above the water table are given in Appendix B (Tables B-11 and B-12). Table 9 compares the EC values from the ceramic cups with those from the drains under the various plots. The average EC of water from the ceramic cups was always greater than the EC of the drain effluent, in many cases nearly twice as great. This fact further demonstrates the inflow of groundwater to the drains from areas outside the farm boundaries. Since the neighboring farmers have historically used flood irrigation methods applying excess water, the water draining from their fields comes through well leached sites. Thus the intruding groundwater tends to dilute the water percolated through the root zone on the Hullinger farm causing the drain effluent to register a lower EC relative to the percolated water.

The above results indicate that although water table depth may be an important factor in managing irrigation for salinity control of return flow, the total seasonal salt discharge was directly related to the quantity of water discharged because there was little change in EC of the drainage water with time. This emphasizes again that management of water is the key to successful return flow quality management. This is true for much of the Upper Colorado River Basin where the concentration of salts in return flow is not too great. It is especially true for soil situations like that of the Hullinger farm where there are large salt source and sink components to flow (discussed in more detail in the following sections). Any control plan which will reduce total discharge of water will probably also reduce total discharge of salts, at least over the short term.

Field Trial 1 - This trial involved putting salty water that had been concentrated in the evaporation pond onto the test plot and measuring the resulting change in soil solution concentrations with time and depth. Two methods of measuring concentration were used - soil water extraction with ceramic samplers and four probe conductivity measurements. Data from the ceramic samplers had the disadvantage that it took several hours of applied suction to get a sample sufficient for measurement. The four-probe conductivity method has the disadvantage of being influenced by soil water content as well as solution

Table 9. SUMMARY OF THE ELECTRICAL CONDUCTIVITY OF WATER COLLECTED FROM CERAMIC CUPS AT 106 cm DEPTH AND FROM THE DRAINS OF VARIOUS PLOTS.

(mmho/cm)

		1972			1973		
Plot	Sample	Low	High	Ave.	Low	High	Ave.
3N	Cups	2.6	5.0	3.8			b
3N	Drain	1.6	2.6	2.1	1.5	2.1	1.8
3M	Cups	2.9	4.6	3.9	1.3	4.1	2.7
3M	Drain			a	2.1	2.4	2.3
3S	Cups	4.1	7.7	5.8			b
3S	Drain			a			a
4N	Cups	1.5	5.4	2.9	2.5	4.4	3.8
4N	Drain	1.1	1.9	1.5	1.5	1.8	1.7
4M	Cups	2.3	4.5	3.5	1.8	4.8	3.5
4M	Drain	1.4	2.7	2.2	1.7	2.5	2.2
4S	Cups	3.3	7.5	4.5			b
4S	Drain	2.2	3.1	2.7			a
5N	Cups	2.4	4.7	3.7	3.5	4.1	3.8
5N	Drain	1.2	2.4	1.8	1.5	2.1	1.8
5M	Cups	1.2	4.4	3.3	2.7	4.0	3.0
5M	Drain	1.2	2.7	2.0	1.8	2.8	2.1
5S	Cups	3.1	4.8	3.9			b
5S	Drain	1.7	2.4	2.2			a
5AN	Cups	0.9	3.7	2.8	1.9	4.3	3.0
5AN	Drain	1.3	3.0	2.3	1.6	2.3	2.0
5AM	Cups	2.4	4.5	3.7	1.8	3.9	2.9
5AM	Drain	1.8	3.0	2.3	2.1	2.9	2.5
5AS	Cups	2.4	4.0	3.5			b
5AS	Drain	1.9	2.4	2.2			a
6N	Cups	1.9	3.9	3.0	2.3	5.1	3.5
6N	Drain	1.2	2.7	1.8	1.4	2.0	1.7
6M	Cups	2.0	3.5	2.5	2.3	4.3	3.2
6M	Drain	1.5	3.3	2.2	1.9	2.7	2.2
6S	Cups	1.7	4.8	3.5			b
6S	Drain	2.8	3.0	2.9			a

[a] No flow.
[b] No data.

conductivity but it has the advantage of allowing rapid reading and many measurements. For the analysis of data, the four probe measurements were first corrected for water content by the use of a calibration equation similar to that suggested by Gupta and Hanks (1972) and were then adjusted by a constant factor to get values corresponding to the approximate EC readings from the ceramic cup water samples. The end result comparing the adjusted four-probe conductivity readings with the ceramic cup samplers is shown in Figure 5. The "raw" data adjusted only for water content are shown in Appendix B (Table B-13). As shown in Figure 5, the agreement between the measured and four-probe conductivities are fairly good before the salty water was added but not as good at the end of the trial.

Figures 6 and 7 show the four-probe estimated conductivity profiles at several times. The data show an increase of EC between the soil surface and about the 45 cm depth after wetting with 10 cm of water at EC of 8.0 mmho/cm and a decrease at deeper depths. Assuming simple piston flow the "salty" water should have penetrated to about 30 cm and the before wetting peak, located at about 60 cm, should have shifted down by about 30 cm. Shifting of the lower peak did not occur. When another addition of 10 cm of water, EC of 4.1 mmho/cm was added there was relatively little change in the salt profile as shown in Figure 6. The addition of water less salty than the solution concentration did not decrease the EC near the soil surface. The data indicate that the addition of large amounts of water at the soil surface had little effect on the soil solution EC in the profile. This same conclusion was born out by the data collected from the ceramic cups.

Field Trial 2 - The September 1972 trial, which was conducted similarly to the August trial but with different EC in the applied water, gave results which led to conclusions similar to the August trial (Figure 7). Wetting with water of EC 4.7 mmho/cm should have caused a depression in EC, if simple piston flow occurred, whereas an increase in surface EC resulted. When the less salty water of EC 1.1 mmho/cm was applied the next day, some depression in EC resulted but it was not nearly as great as expected. The data showed a rather large shift towards lower EC for the entire profile immediately after wetting. However, the profile had shifted back towards higher EC values 35 minutes later. A further shift towards higher EC values was measured in the lower profile a day later. The results of this run indicate the presence of a large "buffering" capacity within the soil. Observed response to water applied can be explained only if considerable precipitation and solution is taking place.

Field Trial 3 - This trial was run at the Hullinger Farm in 1973 where better control on the amount of water applied was attained. In this trial intensive soil sampling was done and the EC determined on 1:5 soil water extracts. The results of the first run, given in Table 10

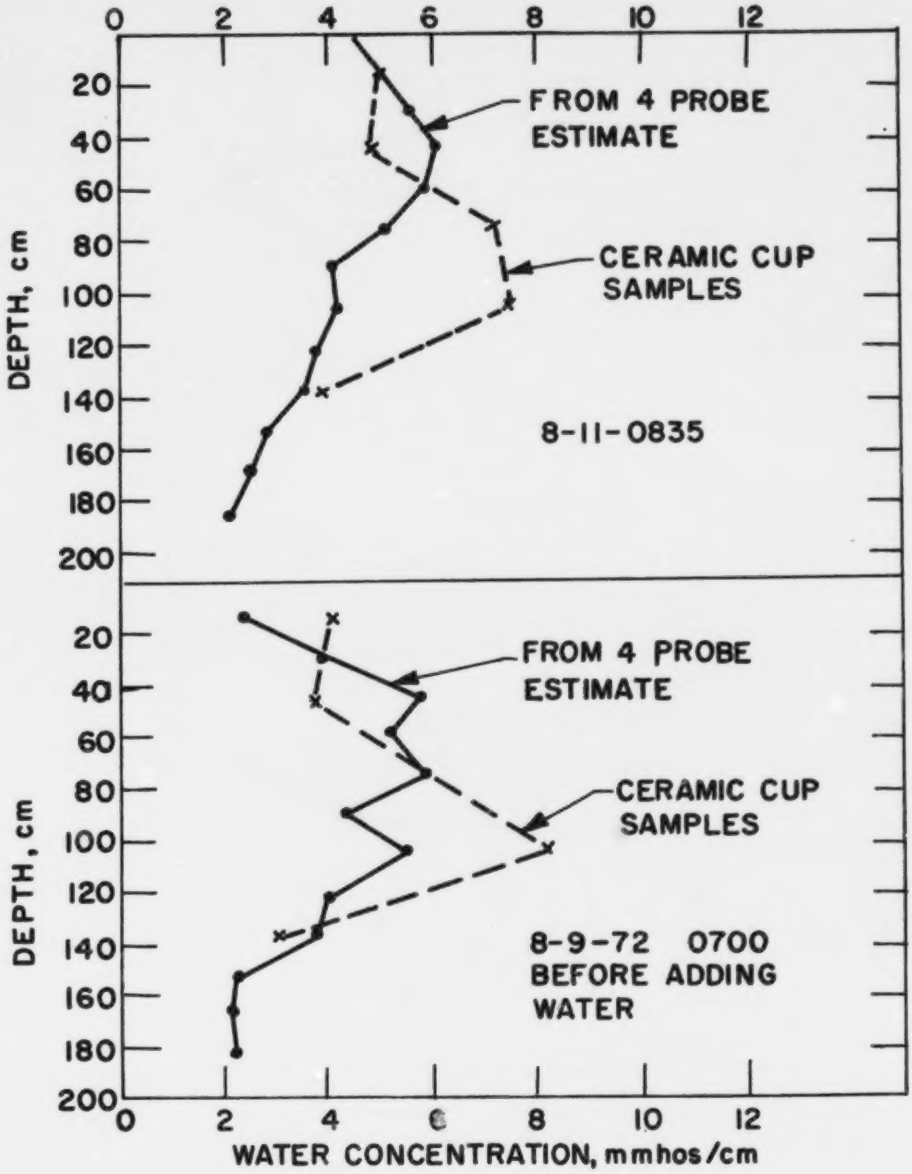


Figure 5. Comparison of electrical conductivity measured from samples taken from ceramic samplers with 4-probe corrected values.

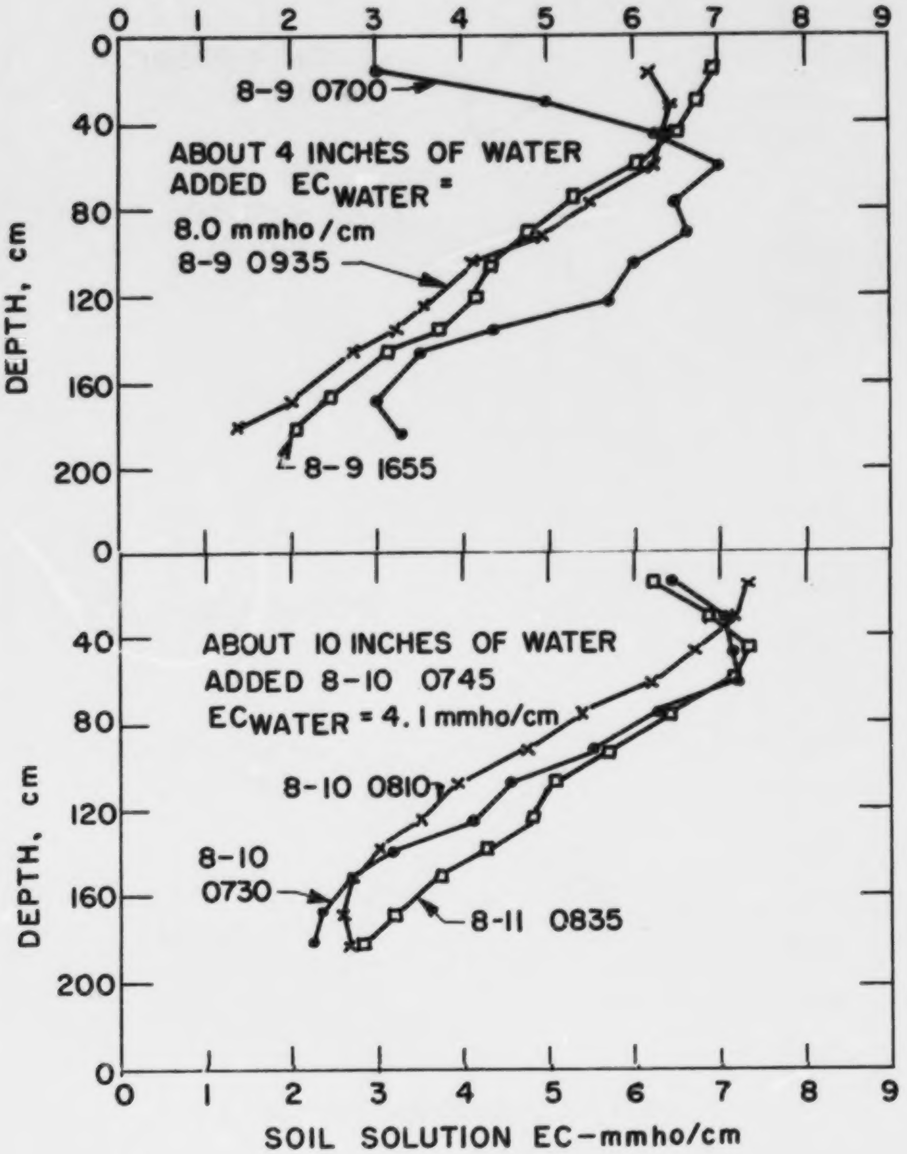


Figure 6. Soil solution electrical conductivity (mmhos/cm) as measured by the 4-probe horizontal probe before and after water application - field trial 1.

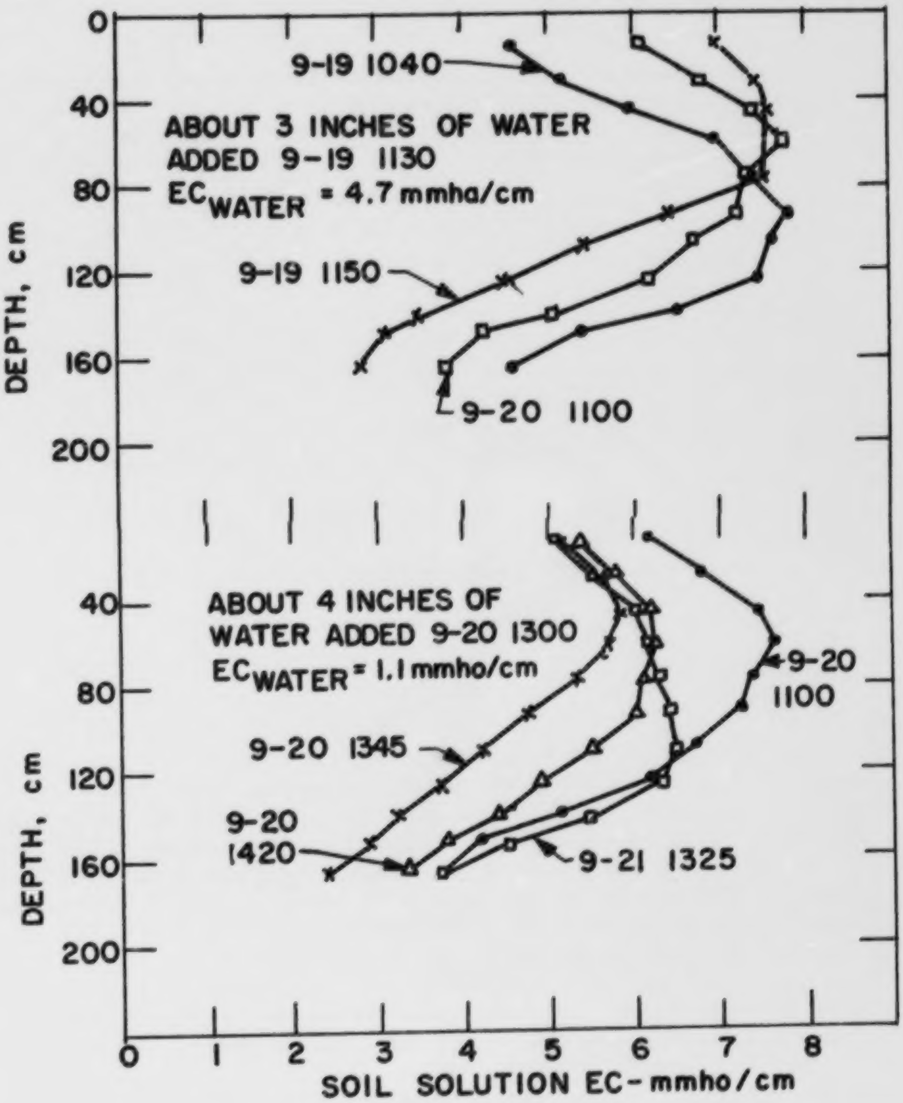


Figure 7. Soil solution electrical conductivity (mmhos/cm) as measured by the 4-probe horizontal probe before and after water application - field trial 2.

Table 10. WATER CONTENT, 1:5 ELECTRICAL CONDUCTIVITY, AND 4 PROBE CONDUCTIVITY (VERTICAL 4-PROBE) FOR FIELD TRIAL 3 FIRST RUN.

Vernal, June 30-21, 1973

Soil Depth cm	Water Content Volume Fraction				4-probe conductivity mmho/cm				1:5 conductivity mmho/cm			
	A	B	C	D	A	B	C	D	A	B	C	D
30	.23	.28	.26	.28	1.9	3.6	3.5	3.3	.20	.17	.20	.20
46	.27	.31	.27	.30	3.8	5.4	4.8	4.9	.18	.20	.26	.20
61	.27	.31	.29	.30	3.7	4.9	5.5	5.8	.18	.18	.25	.25
76	.26	.31	.29	.30	4.2	5.8	6.4	5.2	.25	.18	.30	.26
91	.23	.24	.26	.33	2.1	3.2	3.4	2.8	.26	.25	.29	.28
107	.26	.28	.27	.28	2.7	2.9	3.2	2.8	.25	.25	.21	-
122	.30	.30	.29	.28	2.8	3.0	2.9	3.2	.27	.26	.23	-

A - Readings taken at beginning of test

B - Readings taken after irrigating with about 25 cm of water, EC = 1.5 mmho/cm.

C - Readings taken after irrigating with about 5 cm of water, EC = 10.0 mmho/cm.

D = Readings taken after irrigating with about 5 cm of water, EC = 1.5 mmho/cm.

show that the effect of water content on the 4-probe EC results of treatments B, C, and D should be small since the water contents were essentially constant. The 1:5 conductivity was only slightly higher for treatment C, where salty water had been added, than other treatments. If piston flow occurred, the salty water of treatment C should have been in the top 20 cm and in the 20 to 41 cm zone for treatment D. The data do not indicate this to be the case. This would indicate that the salty water being added to the soil was taken out of solution by some means and does not contribute to the conductivity. The increase in four-probe conductivity above 76 cm between treatment A and B was probably due to the water content increase.

Two sets of ceramic extraction cups were installed at various depths prior to the second run. The data, shown in Table 11, indicate an increase in conductivity as measured by the ceramic samplers for treatment B over treatment A as would be expected. If piston flow occurred, the conductivity down to 46 cm should have been about 10 mmho/cm. The data indicate an actual EC of only 4.6 to 9.5, which is lower than expected. However, the 1:5 EC from the soil samples showed an increase in EC above 60 cm from A to B but again it was less than expected. The increase should have been a factor of 3 to 4 but it was less than two. When water of EC = 1.0 mmho/cm

Table 11. COMPARISON OF ELECTRICAL CONDUCTIVITY, EC, OF SAMPLES EXTRACTED FROM CERAMIC SAMPLERS WITH 1:5 SOIL SOLUTION EXTRACTS. VERNAL, UTAH, AUG. 9-10, 1973 FOR FIELD TRIAL 3 SECOND RUN.

(mmho/cm)

Depth	EC from ceramic samplers							EC from soil samples		
	AS	AN	BS	BN	CS	CN	C LAB	A	B	C
15 cm		2.0		9.5		3.6	4.2	.25	.43	.30
30 cm	1.9	3.2	6.9	4.6	1.3	5.0	4.5	.23	.35	.32
46 cm		2.2		7.4		7.0	-	.22	.34	.30
61 cm			3.1	4.0	2.5	5.3	4.5	.22	.28	.36
76 cm				4.6		3.2	3.1	.25	.35	.35
91 cm			4.4	2.6	4.1	3.4	2.9	.24	.26	.36
107 cm				2.0		1.9	1.9	.22	.25	.34
122 cm								.21	.22	.30
137 cm								.22	.21	.32
152 cm								.17	-	.25
168 cm								.19	-	-

A - Sample collected after irrigation with about 10 cm water, EC 1.0 mmho/cm

B - Sample collected after irrigation with about 10 cm water, EC 10.0 mmho/cm

C - Sample collected after irrigation with about 10 cm water, EC 1.0 mmho/cm

S = South sampling site

N = North sampling site

C LAB is data measured by USU Soil Test Lab collected from the "C" treatment.

was added, treatment C, the ceramic sampler data showed no pronounced shift of the salt peak to a depth of about 46 cm as would be predicted assuming piston flow although there was a decrease in the EC near the surface. The decrease of EC near the surface was less than predicted which is a further indication that solution- and precipitation-like processes are occurring. The EC of the soil samples did increase below 61 cm and decreased only slightly above that depth from treatment B to C as would be expected. Here again, however, the changes are much smaller than would be expected if no solution, precipitation or exchange occurred.

Because it was apparent that some complex chemical changes were occurring, soil and water samples were collected and brought back to the USU Soil Test Lab for more detailed analysis. These data are shown in Table 12. The data indicate that the NaCl water moved almost to 152 cm. The Na concentration before treatment is believed to be about 4 meq/liter. The NaCl water was certainly not "washed" out of the top 46 cm as would be expected if simple piston flow occurred. The data also account for only about 35% of the Na applied (using the soil extraction data). The question remains as to the disposition of the sodium. The 1:100 dilution data indicate that diluting the soil with an excess of water does not bring any more total Na into solution although large amounts of Ca and Mg appear to have come into solution.

To determine whether the EC was lower than expected because of ion pair formation, a calculation of theoretical EC from the chemical data of Table 12 was made by the method of Griffin and Jurinak (1973). If ion pair formation were a factor, the calculation of EC, assuming no ion pairs, would have been lower than that measured. The data show the calculated and measured EC to be the same, so there does not appear to be ion pair formation.

The horizontal four probe measurements made in the field during the second run are shown in Table 13. The increase in EC near the surface, from 1032 to 1440 on August 8, was probably due to increased water content caused by the addition of normal pond water. A further increase from an EC of 53 mmho/cm averaged over the top 61 cm to about 80 mmho/cm, occurred when the salty water was added at 1300 hours on August 9. The further addition of 10 cm of "normal" water caused the average EC of the top 46 cm to decrease from about 76 to 60 mmho. In the 46 to 91 cm depth, the EC increased from 59 to 78 cm due to the last water addition. The average conductivity from 91 to 183 cm varied from 58 to 59 mmho after the first addition of water until the last reading. Thus it is concluded that the data of the horizontal four-probe agree in general with the sample data of EC by the two other sampling procedures used.

Field Trial 4 - Study of salt and water flow was made on Kidman silt loam at the USU Farmington Experiment Station. Water in this trial was added by trickle irrigation, as described in the methods section,

Table 12. CHEMICAL ANALYSIS OF SOIL SOLUTION (FROM SATURATION EXTRACT) AND WATER SAMPLES. AUGUST 10, 1973. ANALYSES BY USU SOIL TEST LAB.

Sample Description		me/liter							mmho/cm	
		ph	Ca	Mg	Na	SO_4	Cl	HCO_3	EC^1	EC
Pond Water (normal)	(A)	8.4	7.6	3.9	0.7	9.3	0.3	3.6	1.7	1.4
Salty Water (NaCl)	(B)	7.6	8.8	4.3	87.0	11.3	97.6	3.8	8.7	8.1
Pond Water (normal)	(C)	8.3	9.0	4.2	0.8	10.0	0.3	-	1.9	1.3
Extractor 15 cm	(C)	8.0	9.4	4.5	28.7	11.0	28.8	-	4.0	4.2
Extractor 30 cm	(C)	7.9	23.1	10.3	12.2	12.0	23.6	-	4.8	4.5
Extractor 46 cm	(C)	8.0	23.8	13.3	6.5	10.3	30.6	4.6	5.0	4.5
Extractor 61 cm	(C)	7.8	16.3	8.1	6.5	12.5	14.5	-	3.5	3.1
Extractor 76 cm	(C)	8.2	17.0	7.8	2.6	16.0	9.4	-	3.6	2.9
Extractor 91 cm	(C)	8.2	12.5	7.0	1.7	12.0	1.1	-	2.5	1.9
Soil 0-15 Sat. Ext.	(C)	-	12.7	5.1	9.6	9.6	14.4	-	3.0	2.6
Soil 15-30 Sat. Ext.	(C)	-	11.9	4.8	13.9	10.7	17.0	-	2.9	2.8
Soil 30-46 Sat. Ext.	(C)	-	12.8	5.7	10.9	8.6	16.9	-	3.1	2.8
Soil 46-61 Sat. Ext.	(C)	-	12.3	6.0	10.0	8.4	15.2	-	2.9	2.7
Soil 61-76 Sat. Ext.	(C)	-	10.7	5.2	9.1	7.4	13.3	-	2.5	2.5
Soil 76-91 Sat. Ext.	(C)	-	9.1	4.1	10.0	7.9	12.0	-	2.3	2.3
Soil 91-107 " "	(C)	-	12.2	5.2	12.6	8.6	17.8	-	3.0	2.9
Soil 107-122 " "	(C)	-	12.3	5.6	10.4	10.6	17.3	-	3.1	2.8
Soil 122-137 " "	(C)	-	15.0	7.4	7.4	11.8	18.3	-	3.6	3.0
Soil 137-152 " "	(C)	-	14.0	6.3	7.8	10.2	15.7	-	3.2	2.8
Soil 0-15 1:100 Ext.	(C)	-	.60	.20	.07	.27	.02	.68	-	-
Soil 15-30 " "	(C)	-	.66	.20	.08	.29	.05	.82	-	-
Soil 30-46 " "	(C)	-	1.09	.28	.08	.10	.02	.86	-	-
Soil 18-24 " "	(C)	-	1.33	.38	.09	.13	.05	.96	-	-
Soil 61-76 " "	(C)	-	1.06	.34	.09	.17	.02	.96	-	-
Soil 76-91 " "	(C)	-	.89	.29	.09	.13	.05	.93	-	-
Soil 91-107 " "	(C)	-	.90	.26	.07	.15	.06	.89	-	-
Soil 107-122" "	(C)	-	.80	.24	.06	.09	.06	.86	-	-
Soil 122-137" "	(C)	-	.83	.24	.04	.07	.06	.86	-	-
Soil 137-152" "	(C)	-	.82	.24	.04	.13	.05	.89	-	-

EC^1 is the calculated conductivity as $EC^1 = \frac{\Sigma z^2 m}{.0137}$ where m is the molar concentration, z is valance (Griffin, R.A. and J.J. Jurinak, 1973).

Table 13. ELECTRICAL CONDUCTIVITY BY THE HORIZONTAL 4-PROBE MEASURED AT VERNAL, UTAH ON AUGUST 8-10, 1973.

Depth cm	Electrical conductivity in mmho/cm 8-8-73 1032	 8-8-73 1440	 8-8-73 1630	 8-9-73 0700	 8-9-73 1445	 8-9-73 1610	 8-9-73 1850	 8-10-73 0615	 8-10-73 0845	 8-10-73 1155
0-15	0.36	0.54	0.54	0.43	0.86	0.85	0.80	0.62	0.64	0.72
15-30	0.31	0.42	0.41	0.37	0.64	0.65	0.65	0.59	0.57	0.56
30-46	0.40	0.54	0.48	0.45	0.94	0.86	0.83	0.60	0.59	0.62
46-61	0.43	0.60	0.62	0.65	0.74	0.68	0.65	0.87	0.90	0.84
61-76	0.67	0.66	0.65	0.67	0.67	0.68	0.57	0.85	0.78	0.81
76-81	0.62	0.64	0.66	0.67	0.60	0.63	0.55	0.61	0.70	0.70
91-107	0.62	0.60	0.54	0.33	0.80	0.67	0.80	0.57	0.62	0.70
107-122	0.52	0.70	0.70	0.93	0.65	0.73	0.50	0.52	0.65	0.65
122-137	0.58	0.60	0.70	0.65	0.70	0.70	0.75	0.91	0.95	0.60
137-152	0.68	0.55	0.50	0.40	0.50	0.55	0.50	0.76	0.60	0.60
152-168	0.47	0.50	0.55	0.45	0.60	0.70	0.60	0.40	0.60	0.60
168-183	0.45	0.55	0.45	0.70	0.20	0.20	0.20	0.55	0.40	0.40

About 10 cm of water, EC = 1.0 mmho/cm, added starting at 1100, 8-8-73

About 10 cm of water, EC = 10.0 mmho/cm, added starting at 1300, 8-9-73

About 10 cm of water, EC = 1.0 mmho/cm, added starting at 1930, 8-9-73

Note that after the first addition of water at 8-8, 1100, the water content was essentially the same throughout the rest of the experiment.

at a very slow rate so that surface water movement on the plot was minimized. The data are shown in Table 14. The data for the ceramic cup samplers showed an increase in EC of the extracted soil solution down to 30 cm after adding the salty water (treatment B). The replicate samples taken show considerable variability. The solution is much less salty than would be expected unless something that effects EC is happening that removes the NaCl from the solution. After more nonsalty water is added (C) ceramic cup sample measurements indicate that there is a slight indication of salt moving down. The 1:5 soil samples indicate almost a doubling of EC from A to B and from C to B. The EC data indicate that most of the added salt had disappeared after treatment C. The salt could certainly have not been removed from the profile by treatment C. Thus the data from this soil show even more strongly than the Vernal trials that something is occurring to remove most of the NaCl from the soil solution. This is again an indication of solution, precipitation of exchange occurring.

The four-probe data taken at the same time and shown in Table 15 indicate an increase in EC from A to B only in the top 30 cm. The 10 cm of water should have moved to about 45 cm so these data seem fairly reasonable. After adding nonsalty water, treatment C, the highest EC was in the 15 to 30 cm depth as was indicated by the ceramic sampler data. The data from the four-probe measurements thus agree in general with the other measured data.

Field Trial 5 - The test made in Logan was to determine if similar effects of adding salty water would show up on another soil. The 1:5 conductivity (Table 16) data show an increase from treatment A to B as would be expected in the 30 to 46 cm samples but the increase should have been much higher if no precipitation of salt occurred. This increased conductivity should have moved down to the 61 to 76 cm depth from treatment B to C. There is some indication that this happened but the increases seem too low. Thus, the data also indicate the NaCl is somehow being tied up so that it is not contributing to conductivity.

Laboratory Studies

Laboratory Trial 1 - Results of laboratory studies involving extraction of soil solution from samples of various water/soil ratios are shown in Figure 8. The measured data of Figure 8 show the high "buffering" capacity of the Vernal soil (A) where increasing the water/soil ratio causes an increase in the relative dissolved salt. These data indicate that for a soil profile of 200 cm deep, about 400 cm of water would have to be leached through the profile (assuming a bulk density of 1.2 g/cm^3) to remove the soluble salts. If the portion of the curve up to a water/soil ratio of 0.5 were linear (line B) it would require 200 cm of water to be leached through the soil before the concentration would change. Under normal irrigation, this may take several years.

Table 14. ELECTRICAL CONDUCTIVITY, EC, FROM CERAMIC SAMPLERS, 1:5 SOIL EXTRACTS AND WATER CONTENT AS A FUNCTION OF TIME AND DEPTH AT FARMINGTON, UTAH. SEPTEMBER 9-10, 1973.

(mmho/cm)

Treatment	EC Ceramic Samples					EC 1:5	Water Content (Vol Fra.)				
Depth	NW	NE	SE	SW	Ave	Samples	NW	NE	SE	SW	Ave
A 15 cm	1.6	0.7	0.9	0.8	1.0	0.08	.22	.27	.25	.27	0.25
A 30 cm	1.0	1.2	0.9	0.8	1.0	.08	.25	.26	.25	.26	.26
A 46 cm	0.7	1.0	1.0	-	0.9	.10	.26	.25	.25	.26	.26
A 61 cm	0.8	0.7	1.2	0.7	0.8	.07	.25	.26	.24	.24	.25
A 76 cm	0.7	0.8	0.8	0.6	0.7	.06	.26	.25	.25	.24	.25
A 91 cm	0.6	0.7	0.8	0.7	0.7	.08	.26	.26	.25	.26	.26
A 122 cm	0.7	0.6	-	-	0.6	.05	.30	.26	-	-	.28
B 15 cm	1.2	1.0	0.7	5.0	2.0	0.16	.25	.28	.27	.26	.26
B 30 cm	2.5	1.0	0.7	0.8	1.3	.16	.27	.28	.26	.28	.27
B 46 cm	1.8	0.7	1.0	0.7	1.0	.16	.27	.26	.24	.26	.26
B 61 cm	1.1	0.7	1.5	1.5	.1	.17	.29	.25	.25	.25	.26
B 76 cm	1.0	0.8	1.8	0.6	1.0	.14	.30	.26	.25	.25	.26
B 91 cm	0.7	0.8	0.8	0.7	0.8	.14	.30	.27	-	.27	.28
B 122 cm	0.8	0.6	-	-	0.7	.15	.31	.26	-	.29	.29
C 15 cm	1.1	0.9	0.9	0.8	0.2	.22	.22	.25	.25	.26	.24
C 30 cm	2.8	0.9	0.8	0.8	1.3	.10	.26	.25	.26	.26	.26
C 46 cm	1.8	0.7	1.0	1.0	1.1	.08	.25	.25	.25	.25	.25
C 61 cm	1.0	0.8	0.8	1.8	1.1	.08	.25	.25	.26	.26	.26
C 76 cm	0.9	0.9	1.2	2.8	1.4	.06	.27	.26	.25	.25	.26
C 91 cm	0.9	0.8	0.8	0.8	0.8	.05	.27	.26	.26	.26	.26
C 122 cm	0.9	-	-	-	0.9	.05	.27	.26	-	-	.26

A - After irrigation with about 15 cm of water EC = 0.4 mmho/cm.

B - After irrigation with about 10 cm of water EC = 5.0 mmho/cm.

C - After irrigation with about 10 cm of water EC = 0.4 mmho/cm.

Table 15. ELECTRICAL CONDUCTIVITY AS MEASURED BY THE HORIZONTAL 4-PROBE AT FARMINGTON.

Depth cm	Before	Treatment[a] A	B	C
0-15	0.14	0.22	0.73	0.39
15-30	.29	.32	.35	.71
30-46	.21	.22	.22	.20
46-61	.25	.29	.30	.20
61-76	.22	.21	.25	.35
76-91	.15	.04	.05	.05
91-107	.10	.25	.30	.30
107-122	.14	.25	.10	.20

[a] Treatments A, B, and C are described in Table 8. Before refers to readings made before any irrigation.

Table 16. WATER CONTENT AND VERTICAL 4-PROBE EC AND 1:5 SOIL EXTRACT FOR LOGAN, JULY 2-3, 1973 TRIAL. EC IN mmho/cm.

	Water Content Volume Fraction			Vertical 4-Probe			1:5 Soil Extract		
	a	b	c	a	b	c	a	b	c
30 cm	0.21	0.23	0.26	1.2	1.4	1.4	0.130	0.260	0.156
46 cm	.21	.20	.22	1.2	1.4	1.4	.130	.150	.134
61 cm	.18	.17	.20	1.3	1.3	1.4	.150	.131	.151
76 cm	.19	.19	.22	1.2	1.1	1.3	.141	.140	.164
91 cm	.19	.19	.22	1.2	1.1	1.2	.161	.130	.140

a - Readings taken after irrigating with about 10 cm of water - EC=0.3
b - Readings taken after irrigating with about 10 cm of water - EC=10.0
c - Readings taken after irrigating with about 10 cm of water - EC=0.3

NaCl was used to increase the EC of treatments b.

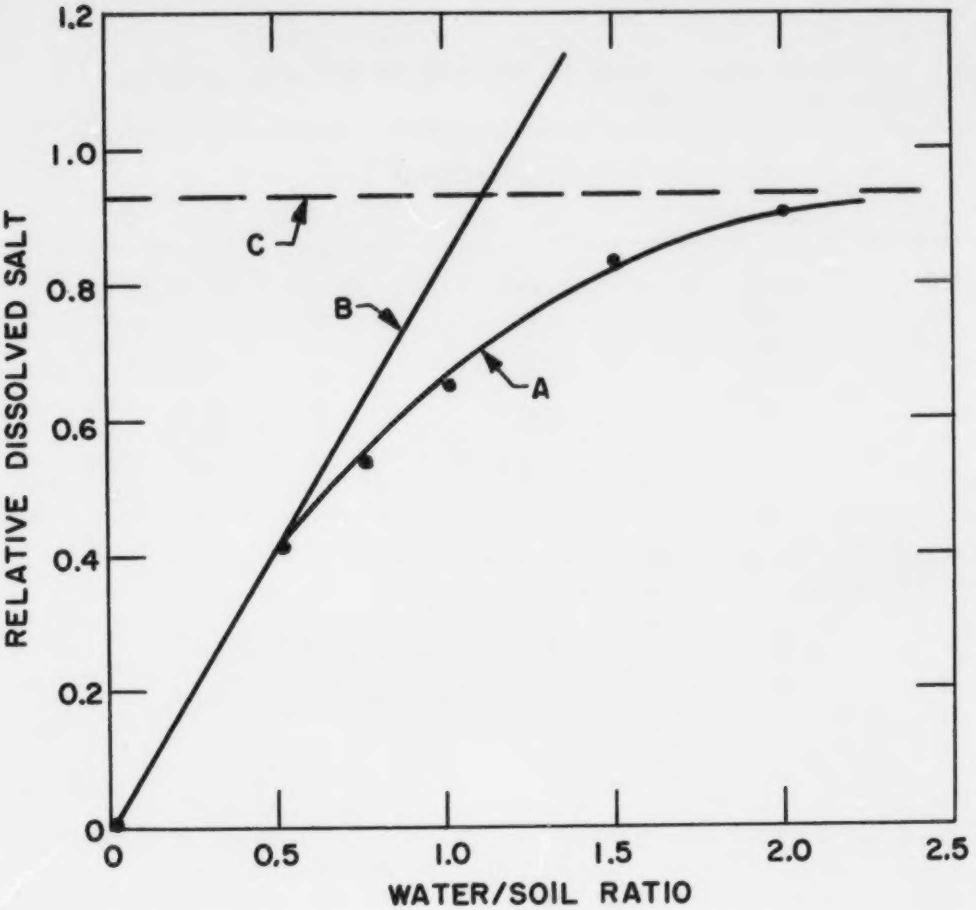


Figure 8. Relative dissolved salt for various water-soil ratios---laboratory trial 1.

For comparative purposes, two other extremes are shown in Figure 8, limited solubility-infinite source (B); and infinite solubility-limited source (C). Limited solubility-infinite source (B) means that the source is enough to saturate the soil solution and the total dissolved salt is directly related to the quantity of the solvent. Infinite solubility-limited source means that the quantity of extracted salt is independent of the quantity of the solvent. The measured data (A) show features similar to both extremes. When the water/soil ratio is low, the soil appears as an infinite source with limited solubility. When the water/soil ratio is high the soil approaches a system with a limited source of infinite solubility. The soil undoubtedly has a mixture of many salts having different source strengths and solubilities.

Laboratory Trial 2 - Figure 9 summarizes the results of the short column leaching study. About 16 pore volumes of water were needed to complete the leaching. Salt balance calculations for this experiment accounted for all but about 2.5 percent of the total salt, indicating reasonable accuracy for the experiment. Figure 9 shows the ratio of C_o/C as a function of pore volume of effluent. Figure 10 shows EC (4P) for each segment of the column and effluent EC as functions of pore volume of effluent. Figure 11 shows a comparison of effluent EC with EC ($4P_3$) of the bottom segment of the column. The data indicate a good linear relation between the two methods of estimating EC. Thus it appears that the EC (4P) may be capable of estimating EC of the soil solution in small saturated columns once a good calibration for the soil and geometrical configuration of the 4 electrodes is attained.

It is apparent from the results of the short column leaching study that a large quantity of water is required to completely leach the soil. Thus there must be large quantities of relatively low solubility salts existing in this particular soil.

Model Predictions

The procedure followed in using the model was to compute the consequences of various given irrigation management sequences for a typical season as a function of soil and crop conditions for that season. The following inputs were varied and the outputs as a result of the variation were predicted.

Input Data - Irrigation was applied according to the irrigation frequency actually used in 1971 which was described in detail in King and Hanks (1973). The ET_p relations were also the same as given earlier for 1971. The amount of irrigation applied each time was varied from zero to sufficient to cause considerable damage. Thus the irrigation frequency was the same for all treatments but the irrigation amounts were different.

The initial salt concentration of the profile was assumed to be uniform at the beginning of the season at 20, 50, or 200 meq/1. The 20 meq/1 concentration was about the same as conditions existing on the Hullinger farm. The 50 and 200 meq/1 were used to simulate salt buildup that would occur over several years time if proper irrigation and drainage were not practiced.

Three root depths were simulated--shallow, medium, and deep. Since calculations estimated only dry matter these results apply for forage and could be less accurate if grain yield predictions are made (Hanks, 1974).

The shallow rooted crop was assumed to be an annual crop, like oats, which developed full cover fairly quickly. The medium rooted crop

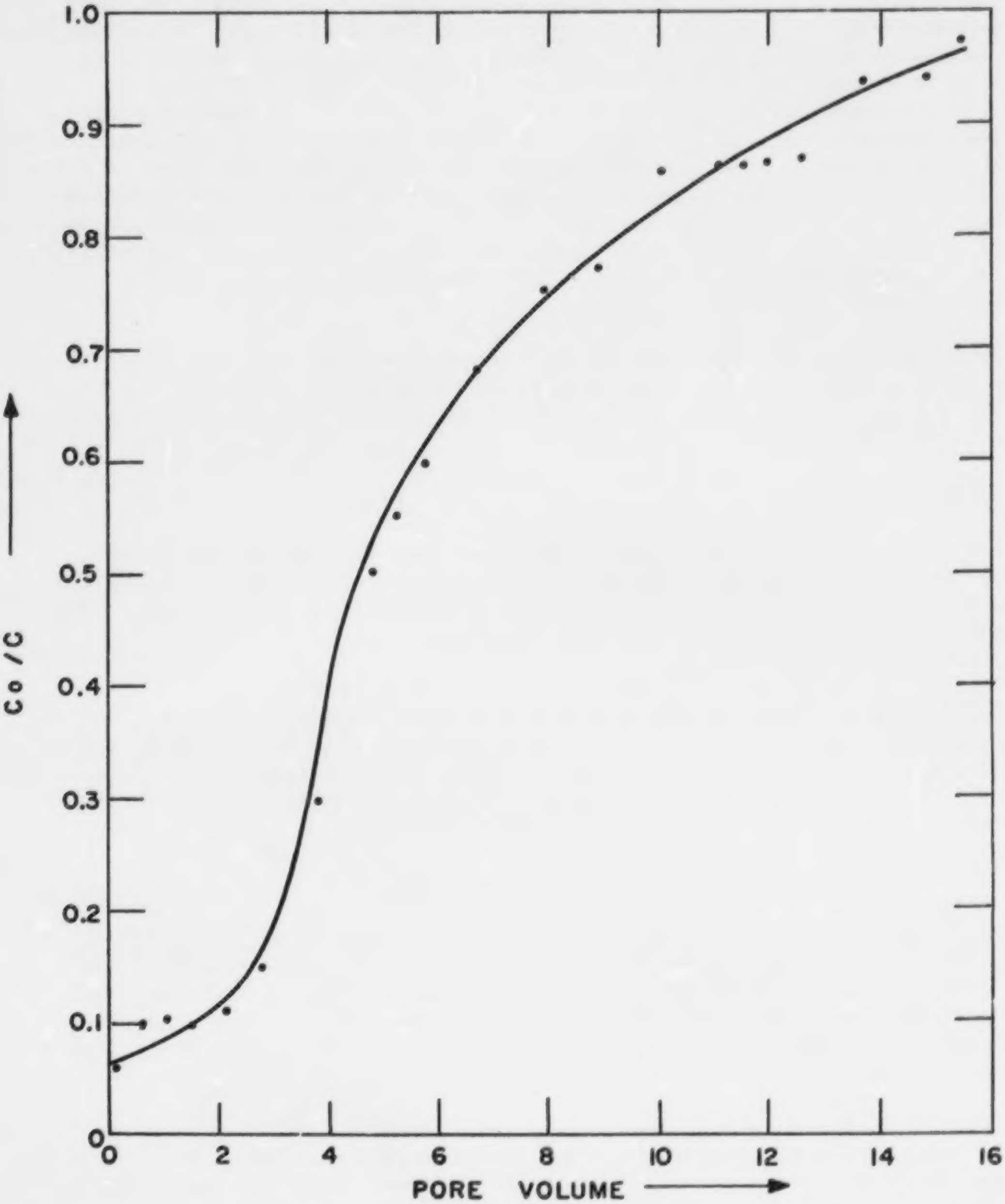


Figure 9. Ratio of EC of irrigation water to EC of effluent as a function of pore volume of the effluent - laboratory trial 1.

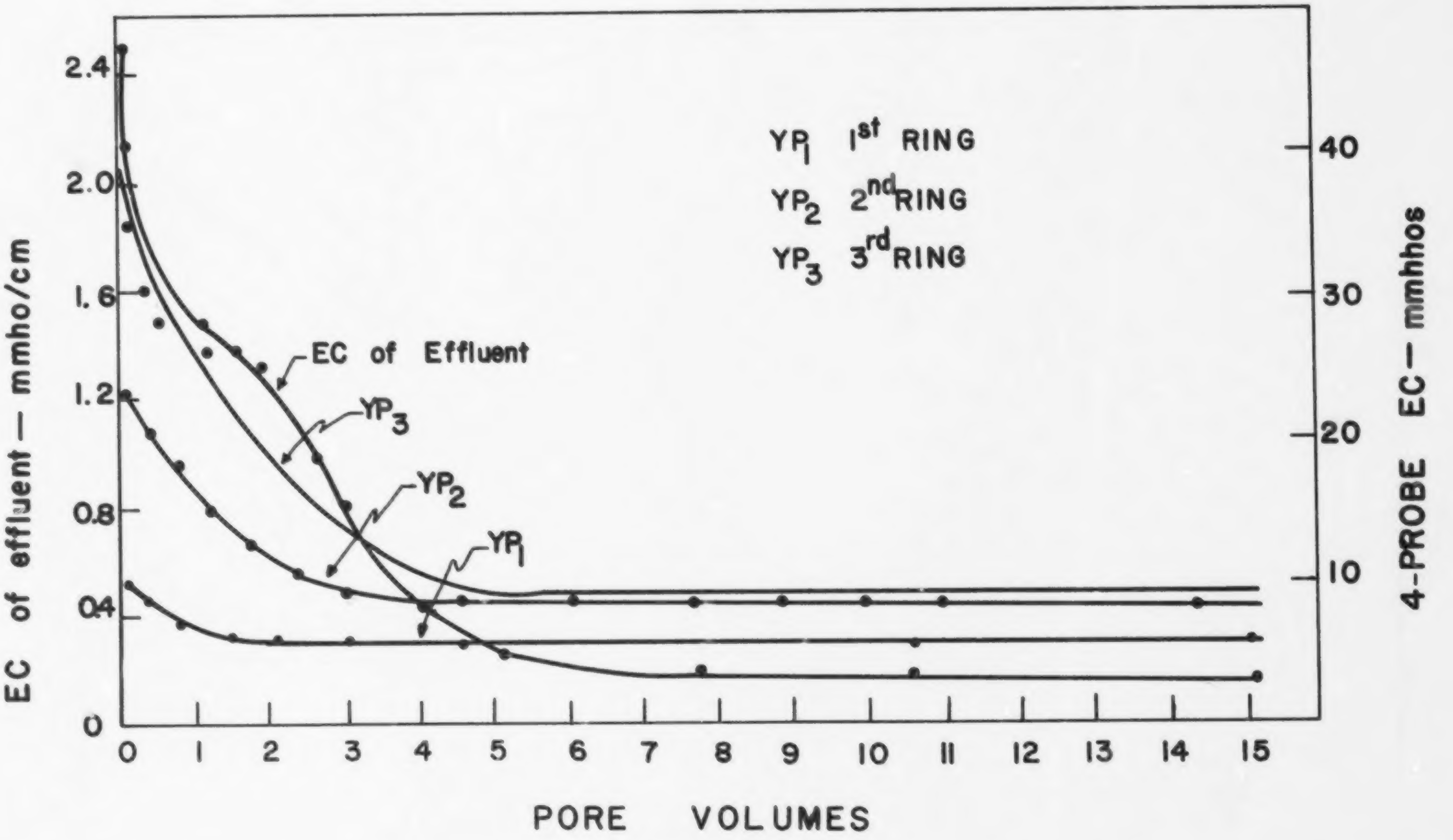


Figure 10. Comparison of curves for effluent EC and 4-probe EC as related to pore volume - laboratory trial 2.

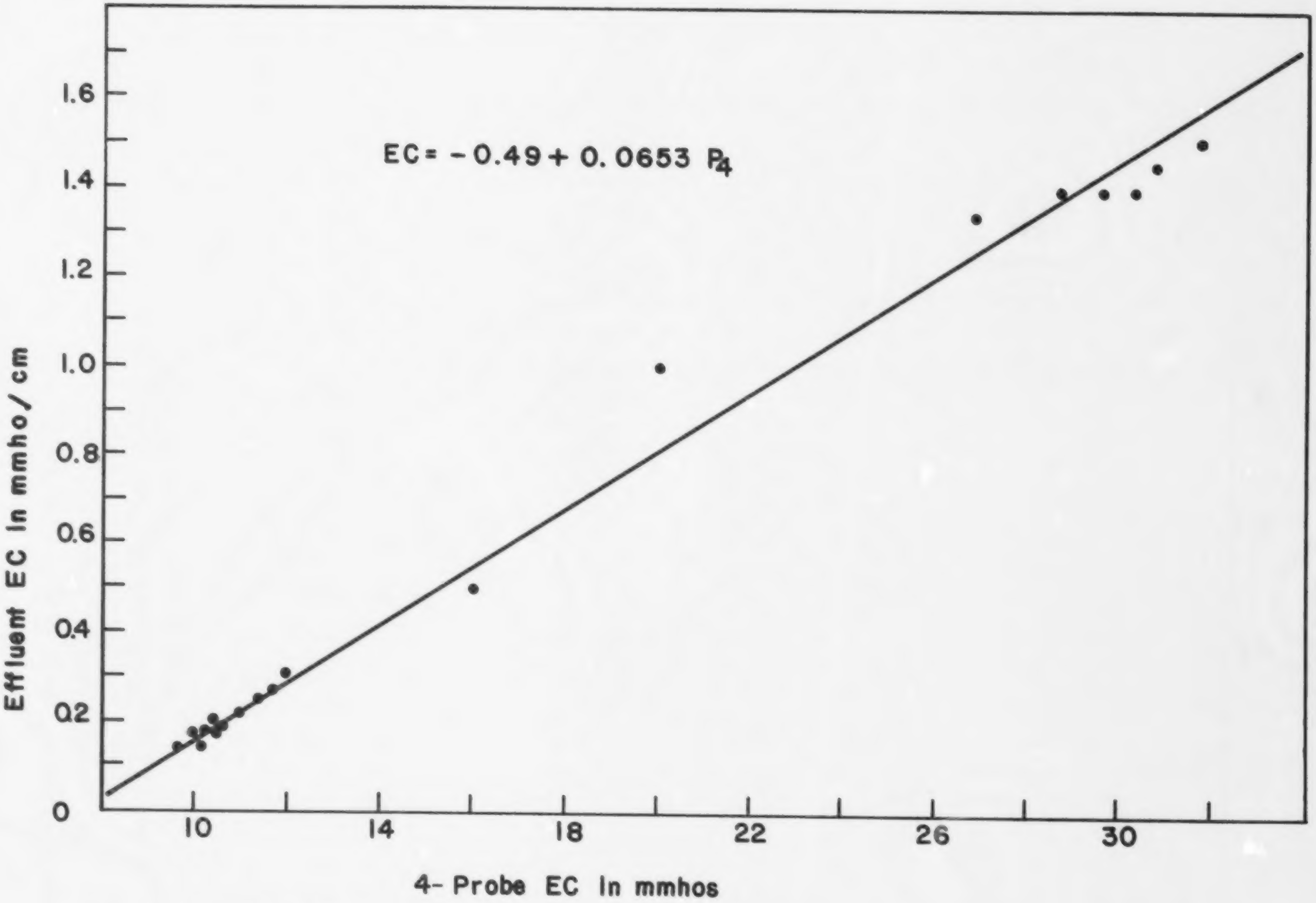


Figure 11. Comparison of effluent EC with 4-probe EC of bottom column section - laboratory trial 2.

was assumed to be a perennial crop, like alfalfa, which had full cover all year. The deep rooted crop was assumed to be an annual row crop, like corn, which started out with bare soil and took about 60 days to develop full cover. Computations made show that the year end results are only slightly influenced by these root depth and cover development assumptions.

Table 17 shows the root distribution function used. The initial water content profile and soil water properties were assumed to be the same as those of 1971. These data are given in King and Hanks (1973). The salt concentration of the irrigation water was originally used as a variable. However, after some preliminary computation with rather drastic changes in concentration, it was apparent that this input has little influence on the results and would have an effect only after several years. Thus the irrigation water was assumed to have a concentration of 6.35 meq/l throughout. Thus yearly buildup was simulated as different initial salt concentrations. There was an assumed water table at 235 cm which had a constant concentration equal to the initial concentration of soil solution throughout the season.

Predicted Results - Table 18 shows the effect on various soil and water properties of varying the water added and initial salt concentration for the deep rooted crop. The data on T/T_p is of primary interest because it is assumed to be directly related to relative yield. The data in Table 18 show, as would be expected, that T/T_p increases as the irrigation applied increased up to about 46 cm after which the ratio was essentially 1.0 for all initial salt concentrations. However, T/T_p was less than 0.9 where irrigation was less than 6, 9, and 26 cm for an initial salt concentration of 20, 50, and 200 meq/l respectively. There was relatively little difference on T/T_p due to an initial salt concentration of 20 or 50 meq/l but there was a marked influence when the initial salt concentration was 200 meq/l. Thus the irrigation management used with the 20 meq/l initial profile salt concentration can be considered to be nearly salt free and the results are due to water influences only. Note that where the irrigation and rain was less than about 20 cm there was nearly an equal amount of upward water flow from the water table showing that the amount of flow was limited by soil water transmission and plant root extraction. Where the initial salt concentration was 200 meq/l, upward flow was about 2.5 cm less than for the higher initial salt concentrations. However, drainage (downward flow) was influenced very little by initial salt concentration.

A unique feature of the data shown in Table 18 is the large influence of water movement up from the water table (at 235 cm). The soil properties at the Hullinger Farm seem to be especially conducive to high water flow in both directions. Other situations with other soils would probably not result in as much upward flow as shown in Table 18.

Table 17. RELATIVE PROPORTION OF ROOTS AT DIFFERENT DEPTH INCREMENTS AT MATURATION ASSUMED.

Depth (cm)	Deep	Medium	Shallow
2.5 to 10.5	.09	.14	.18
10.5 to 25.5	.20	.30	.40
25.5 to 52.5	.34	.33	.42
52.5 to 91.5	.25	.23	0
91.5 to 140.0	.12	0	0
140.0 to 235.0	0	0	0

The data shown in Table 18 are only a small part of the data generated by the model to attain these summary values. Each line represents one complete season where data has been computed at several depth increments and at no greater than 2 to 3 hour time increments. Thus data within the season are also available. Figure 12 shows a comparison of cumulative evapotranspiration as influenced by initial salt concentration for two different irrigation levels.

Table 19 shows the computation made for a medium rooted crop. The data show greater decreases in T/T_p for low irrigation rates than were shown for a deep rooted crop. Upward water flow was less for the medium than for the deep rooted crop. The data show little difference between the 20 and 50 meq/1 initial salt concentrations but fairly large differences with 200 meq/1 initial salt concentrations. Thus the T/T_p depression at 20 meq/1 initial salt concentration is due to inadequate irrigation. The differences in T/T_p at any one irrigation level, between 20 and 200 meq/1, were due slightly to a salt effect. Where 15 cm of irrigation and rain was applied T/T_p was 0.68 because water was insufficient to maintain transpiration. A further reduction of T/T_p from 0.68 to 0.49 resulted from the high initial salt concentration.

Table 20 shows the computed data for the shallow rooted crop. The values of T/T_p were smaller for the shallow rooted crop, for a given irrigation regime, than for either of the deep rooted crops. With the shallow root zone, upward flow was less than 4 cm. This caused the ratio, T/T_p, to be less than 0.9 (for 20 meq/1 initial salt concentration) where irrigation and rain was less than about 52 cm. The T/T_p

Table 18. COMPARISON OF IRRIGATION WATER APPLIED AND INITIAL SALT CONCENTRATION ON RELATIVE TRANSPIRATION, T/T_p, TOTAL WATER USED, DRAINAGE, SALT FLOW TO THE GROUNDWATER AND AVERAGE FINAL SALT CONCENTRATION FOR THE DEEP-ROOTED CROP.

Irrigation and Rain (cm)	ET (cm)	T	T/T_p	Drainage (cm)	Salt Flow to Groundwater (meq)	Initial Salt Concentration (meq/1)	Final Salt Concentration Average (meq/1)
5.6[b]	40.3	35.3	.81	-14.2[a]	- 284	20	62
5.6	38.6	33.5	.77	-14.2	- 710	50	127
5.6	6.2	20.6	.48	-11.6	-2320	200	305
10.3	3.9	36.6	.89	-14.1	- 282	20	60
10.3	2.1	35.1	.86	-14.0	- 700	50	120
10.3	30.1	22.3	.55	-11.4	-2280	200	296
15.0	47.7	38.6	.97	-14.0	- 280	20	56
15.0	46.3	37.2	.93	-13.9	- 695	50	116
15.0	34.6	25.1	.64	-11.4	-2280	200	296
22.0	9.0	38.5	.98	-13.6	- 272	20	40
22.0	9.2	38.7	.98	-13.5	- 675	50	95
22.0	1.2	30.9	.78	-11.9	-2260	200	291
40.8	50.4	37.6	.99	- 8.7	- 174	20	27
40.8	48.3	35.9	.98	- 7.1	- 355	50	604
40.8	48.1	35.8	.97	- 6.2	-1240	200	227
56.4	51.9	37.3	1.00	+ 0.91	19	20	23
56.4	52.2	37.3	1.00	+ 1.0	49	50	50
56.4	56.7	37.3	1.00	+ 1.1	214	200	189
66.7	51.7	37.3	1.00	+10.5	210	20	20
66.7	51.6	37.3	1.00	+10.6	532	50	42
66.7	51.6	37.3	1.00	+10.8	2160	200	153

[a] A negative sign indicates upward flow.

[b] Rain was 5.6 cm. Each line represents a computation for the same irrigation efficiency but different amounts of water applied, for the 1971 climatic conditions at Vernal, Utah.

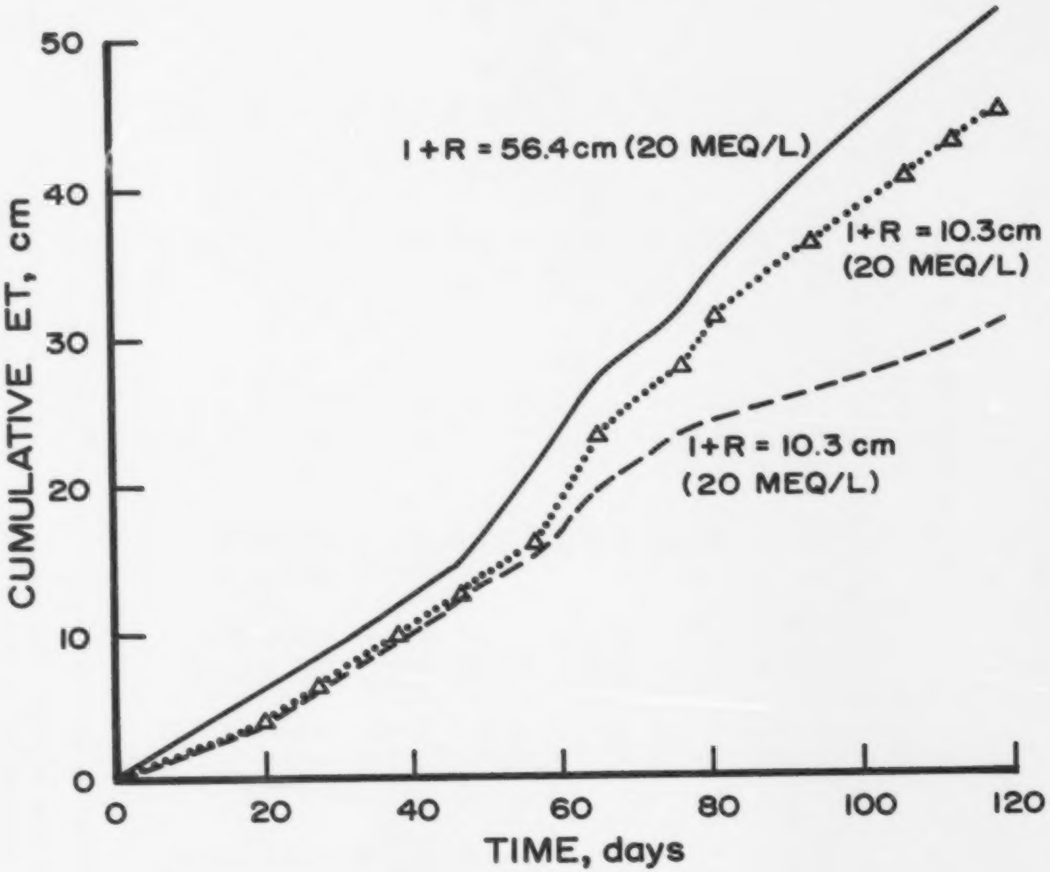


Figure 12. Comparison of cumulative evapotranspiration vs. time for two water application amounts and two initial soil solution concentrations.

Table 19. COMPARISON OF IRRIGATION WATER APPLIED AND INITIAL SALT CONCENTRATION ON RELATIVE TRANSPIRATION, T/T_p, EVAPOTRANSPIRATION, ET, DRAINAGE, SALT FLOW TO THE GROUNDWATER AND AVERAGE FINAL SALT CONCENTRATION FOR THE MEDIUM-ROOTED CROP.

Irrigation and Rain (cm)	ET (cm)	T	T/T_p	Drainage (cm)	Salt Flow to Groundwater (meq)	Initial Salt Concentration (meq/l)	Final Salt Concentration Average (meq/l)
5.6[b]	29.5	25.8	.52	-9.7[a]	- 195	20	43
5.6	28.2	24.6	.50	-9.4	- 472	50	97
5.6	19.8	16.0	.33	-7.8	-1561	200	277
10.3	33.2	29.2	.61	-9.5	- 189	20	42
10.3	32.1	28.1	.58	-9.3	- 466	50	94
10.3	24.2	20.0	.42	-7.7	-1860	200	269
15.0	37.6	32.8	.68	-9.3	- 154	20	43
15.0	36.5	31.8	.66	-9.2	- 458	50	94
15.0	28.8	23.7	.49	-7.6	-1840	200	268
22.0	43.9	38.6	.80	-9.4	- 148	20	41
22.0	42.9	37.6	.78	-9.2	- 461	50	92
22.0	35.3	30.1	.63	-7.5	-1840	200	263
40.8	51.7	46.7	1.00	-7.4	- 148	20	30
40.8	51.3	46.3	1.00	-6.7	- 370	50	64
40.8	48.1	43.2	.93	-5.6	-1340	200	228
56.4	53.4	48.2	1.00	0.0	0	20	24
56.4	53.9	47.9	1.00	+0.4	22	50	52
56.4	53.9	47.9	1.00	+0.3	61	200	195
66.7	53.5	48.3	1.00	+8.8	178	20	22
66.7	53.1	48.3	1.00	+9.3	467	50	44
66.7	53.2	48.3	1.00	+9.4	1882	200	158

[a] A negative sign indicates upward flow.

[b] Rain was 5.6 cm. Each line represents a computation for the same irrigation efficiency but different amounts of water applied, for the 1971 climatic conditions at Vernal, Utah.

Table 20. COMPARISON OF IRRIGATION WATER APPLIED AND INITIAL SALT CONCENTRATION ON RELATIVE TRANSPIRATION, T/T_p, EVAPOTRANSPIRATION, ET, DRAINAGE, SALT FLOW TO THE GROUNDWATER AND AVERAGE FINAL SALT CONCENTRATION FOR THE SHALLOW-ROOTED CROP.

Irrigation and Rain (cm)	ET (cm)	T	T/T_p	Drainage (cm)	Salt Flow to Groundwater (meq)	Initial Salt Concentration (meq/l)	Final Salt Concentration Average (meq/l)
5.6[b]	18.3	13.3	.29	- 3.8[a]	- 74	20	33
5.6	18.0	12.9	.28	- 3.8	-191	50	78
5.6	14.3	8.2	.18	- 3.6	-718	200	248
10.3	22.7	16.4	.37	- 3.8	- 76	20	33
10.3	22.2	16.1	.36	- 3.8	-190	50	76
10.3	18.4	10.2	.24	- 3.5	-700	200	242
15.0	27.1	20.2	.46	- 3.8	- 76	20	33
15.0	26.7	19.4	.44	- 3.8	-189	50	76
15.0	22.9	13.3	.32	- 3.5	-700	200	242
22.0	33.8	25.6	.59	- 3.8	- 76	20	33
22.0	33.4	25.3	.58	- 3.8	-190	50	76
22.0	29.5	19.3	.46	- 3.3	-660	200	40
40.8	46.0	35.2	.89	- 2.5	- 50	20	26
40.8	45.7	35.1	.88	- 2.4	-120	50	58
40.8	42.3	31.5	.80	- 1.2	-240	200	208
56.4	53.6	38.5	.97	+ 1.3	26	20	24
56.4	53.4	38.8	.98	+ 1.3	66	50	52
56.4	51.4	37.0	.93	+ 2.5	490	200	185
66.7	52.5	38.6	.99	+10.0	198	20	20
66.7	52.5	38.6	.99	+10.0	495	50	43
66.7	52.5	38.6	.99	+ 9.9	1975	200	157

[a] A negative sign indicates upward flow.

[b] Rain was 5.6 cm. Each line represents a computation for the same irrigation efficiency but different amounts of water applied, for the 1971 climatic conditions at Vernal, Utah.

results with 50 meq/l initial salt concentration were only slightly different than for 20 meq/l whereas, the T/T_p results for 50 meq/l were considerably larger where the initial salt concentration was 200 meq/l.

A feature of the model computation is especially noticeable in Table 18 for the deep rooted crop. The computer program allows for the possibility that if evaporation is less than potential evaporation, the difference, $E_p - E$, can then be used in transpiration. Thus potential transpiration is not a constant in Table 18 but increases as applied irrigation and rain decreases. Thus for a rain of 5.6 cm, T_p was 40.3 and for irrigation and rain of 56.4 cm, T_p was 37.3 cm. Hanks et al (1971) demonstrated that this energy "trading" occurs, but it may be that the model computation over corrects for it.

Figure 13 shows the salt concentration profile at the end of the season compared to the initial salt concentration for three different levels of water addition for the deep rooted crops. Where irrigation was insufficient to cause drainage, there was a higher concentration of salt throughout the profile at the end of the season than at the beginning. There was a very pronounced peak in salt concentration just below the root zone particularly for small water applications.

Figure 13 also shows the salt concentration profiles at the end of the year for the shallow rooted crops. The salt concentrations are higher in the profiles than for the deep roots because of the more shallow root distribution. With rain only there was relatively little water available for transpiration so the salt peak was lower than where 22 cm of irrigation and rain provided sufficient water for more transpiration and thus more concentration of salt. Where sufficient water for some leaching was available the salt concentration was essentially constant throughout the profile.

Figure 14 shows a simulation over several years where irrigation and rain were about one-half ET. The data indicate no decrease in the T/T_p ratio until the seventh year, after which the ratio fell rapidly until the 10th year when it appeared to be leveling off. Figure 14 also shows the average salt concentration buildup which by the 10th year had almost leveled off at about 260 meq/l. Where T/T_p decreases, the transpiration decreased until the 10th year ET had decreased by 15 cm and was only 9 cm greater than the water added. The difference between the water added and ET came from soil water storage and water flow up from the water table. Note that the particular results computed for a simulated run of 10 years, is highly dependent on the particular situation. If a crop with shallower roots had been used, an entirely different result would have been obtained.

One of the purposes of the computation over several years time was to see how these results compared with the data of Table 18 where different initial salt concentrations were used to simulate salt build up. For the same irrigation schedule, the data of Table 18 indicate a T/T_p

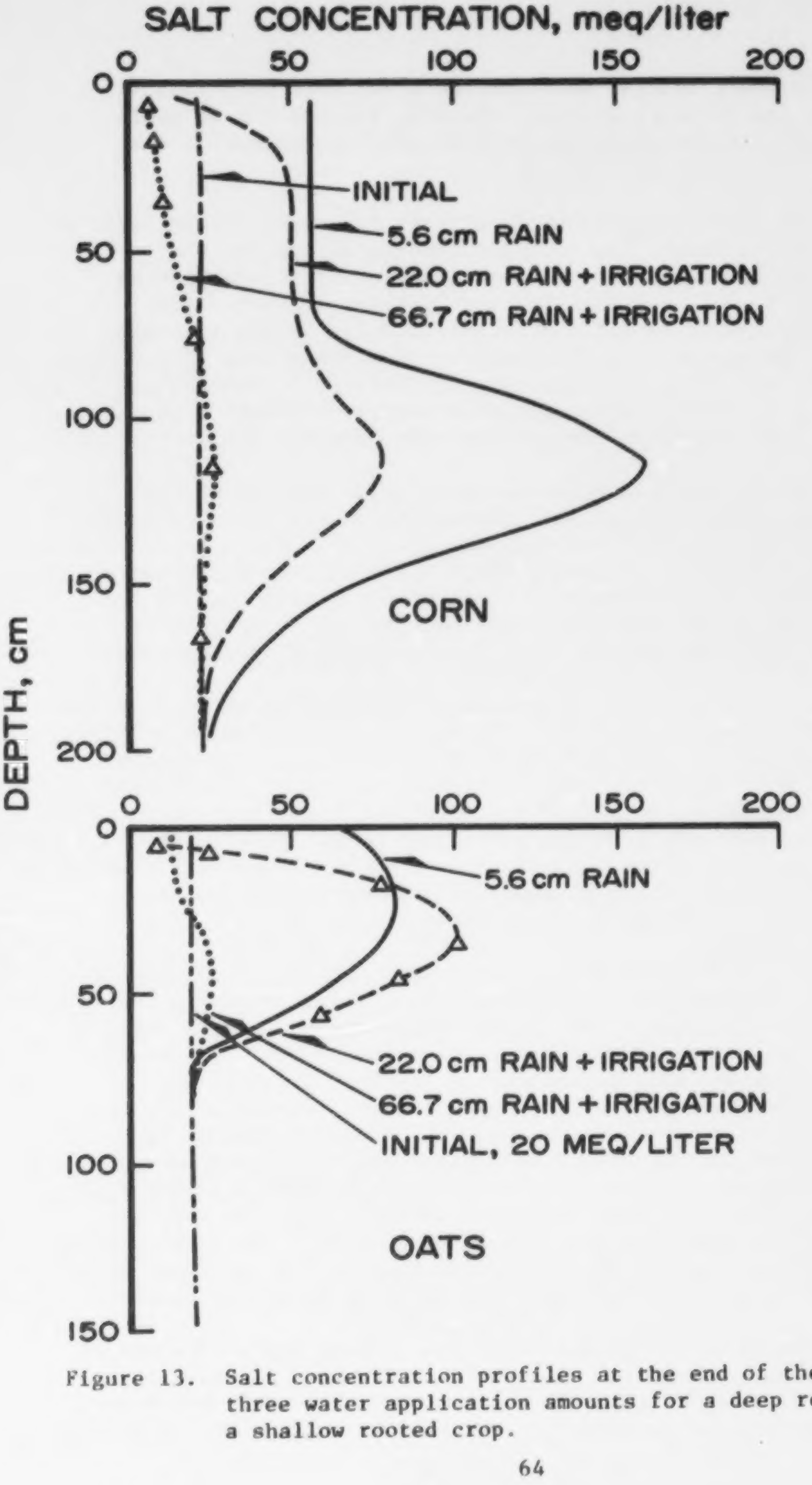


Figure 13. Salt concentration profiles at the end of the season for three water application amounts for a deep rooted crop and a shallow rooted crop.

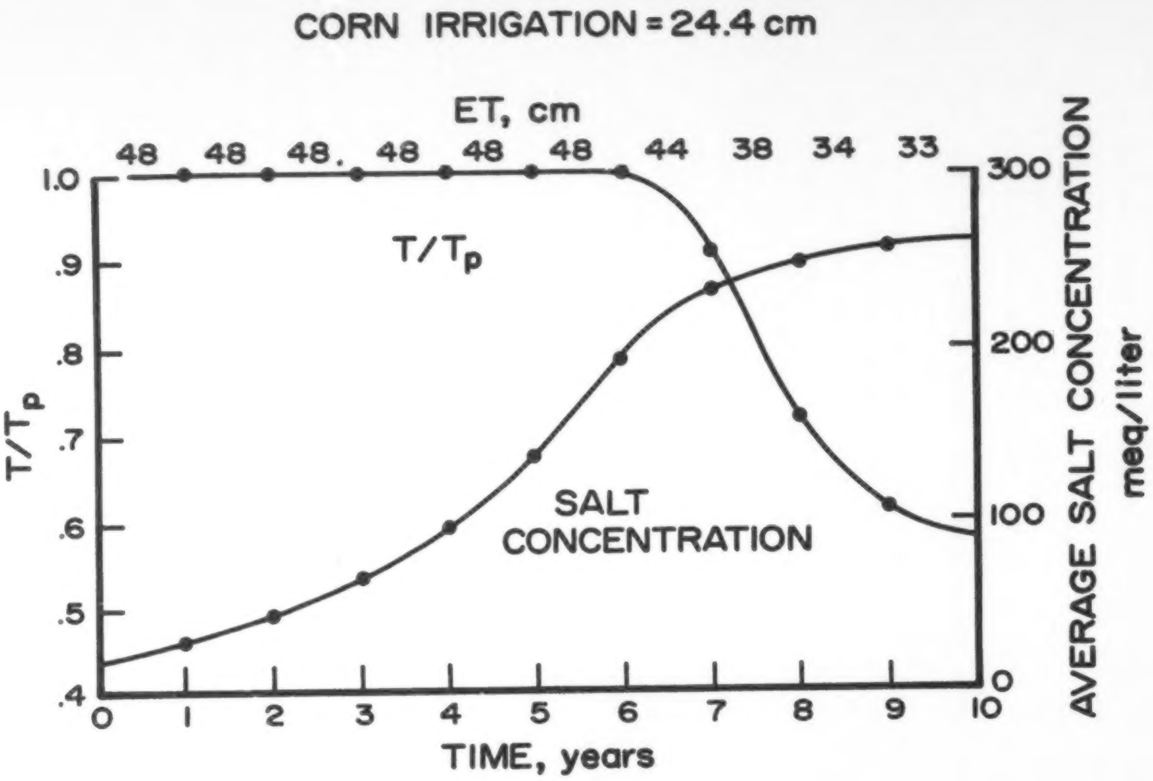


Figure 14. Computations made of relative transpiration, T/Tp, and average salt concentration as influenced by time where the water application amount was about 22 cm deep for the deep rooted crop.

ratio of 0.90 for an initial salt concentration of 200 meq/l that ended one season with an average profile salt concentration of 296 meq/l. The data of Figure 14 indicate essentially the same ratio of T/T_p although the salt concentration at the end of that particular year is not as high as that of Table 18. Thus it is concluded that assuming an initial uniform salt concentration throughout the profile at the beginning of the year gives essentially the same results as taking the developed concentration profile from the previous year.

Using the concentration profile at the end of the crop season for the input data for the next spring may be somewhat erroneous because the profile would tend to equalize somewhat over the winter by diffusion and mass flow up and down due to rainfall, evaporation, and drainage.

Validity of Model Predictions - In view of the apparent high "buffering" capacity of the different soils on which field and laboratory tests were made, the question arises--how valid are the model calculations? If the field measurements are taken as being representative of what happens during normal management manipulations, a model could be devised which would account for water flow and the assumption made that salt concentrations would not change appreciably with time. Thus to compute salt flow it would only be necessary to multiply the water flow by the salt concentration at the bottom of the profile. This approach would probably be valid for many years where leaching is moderate (about 10 percent of the irrigation). Thus little influence of salinity management on crop yield would result. Estimates made by the simple salt flow model, as done herein, would yield results that tend to overestimate the effects of salinity on crop yield if some salt storage (by precipitation, solution exchange, etc.) takes place. Thus the true picture is probably somewhere in between. There is a certain danger in the conclusion that salt buildup will not be harmful, because this can be true only for a limited number of years. It would seem more useful to use the more conservative estimate.

Another factor that would tend to favor use of the conservative approach for management prediction would involve the assumption that the osmotic component is the only detrimental effect of salinity. This assumption would tend to counterbalance the neglect of salt being taken out of the soil solution.

Regardless of which of the two extremes is used to develop a model, it is apparent that salinity effects do not occur in a short time but rather develop over many years and are thus capable of being influenced by many factors. This long term effect makes conclusions based on a few years of field research very risky indeed.

NITROGEN MOVEMENT

Commercial Fertilizer Plots

Plots (30.5 m x 54.9 m) treated with $Ca(NO_3)_2$ in 1972 were planted part to corn and part to alfalfa (see Figure 1). Figure 15, shows nitrate nitrogen data taken shortly after $Ca(NO_3)_2$ additions and illustrates that the NO_3-N was in the surface 30 cm and in about the correct proportions for the 110 kg/ha and 440 kg/ha rates in the corn plots. See Appendix B, Table B-14 for detailed data. However, to have all of the added NO_3-N evenly distributed in the 0-30 cm depth would produce a leaching of about 90 ppm for the 440 kg/ha rate. The NO_3-N added to alfalfa was irrigated into the soil. Obviously some of the NO_3-N was leached below 30 cm.

After the growing season, soil samples showed a higher NO_3-N content in the corn plots treated with 110 kg/ha than 440 kg/ha of NO_3-N (Figure 16). This result must be due to an error in sampling because a total of only about 25 ppm would be expected if all of the fertilizer was contained in the profile. The September sample of the 0-30 m depth also is low which would cause the October data to be questioned. The values in the 440 kg/ha treatment seemed more realistic, assuming there was little leaching or gaseous losses. About 90 to 100 ppm total would account for all added NO_3-N at the 440 kg/ha rate. Figure 15 illustrates that alfalfa plots had less extractable NO_3-N than the corresponding corn plots. Additional soil samples of the top 30 cm of soil taken in September 1972 showed less than 4 ppm NO_3-N extracted for all samples (Figure 16). This would have been near maturing time for the corn and may have had lower NO_3-N levels than would exist in October.

The 1973 soil samples indicated similar NO_3-N contents for many of the treatments (Figure 17). The figure shows alfalfa and corn plots grouped together. The separated average values are shown in Table 21 (see Table B-15, Appendix B for detailed data). Generally, alfalfa plots with the same added fertilizer were lower in NO_3-N than were corn plots. However, the difference is not as marked as is indicated by the 1972 data (Figure 16). Assuming that some NO_3-N might be residual from the previous year, a summation of about 150 ppm NO_3-N in the four 30-cm increments might be expected for the 440 kg/ha rate. About 40 to 50 ppm might be expected in the 110 kg/ha rate. The values for corn plots do not exceed these estimates in the June 20 sampling if the values for the control plots are subtracted to approximate only added NO_3-N. By September 19 the total NO_3-N had decreased in all treatments. Some loss estimates of NO_3-N based on general conversion values are given in Table 22. These losses may be conversions to organic forms or actual losses.

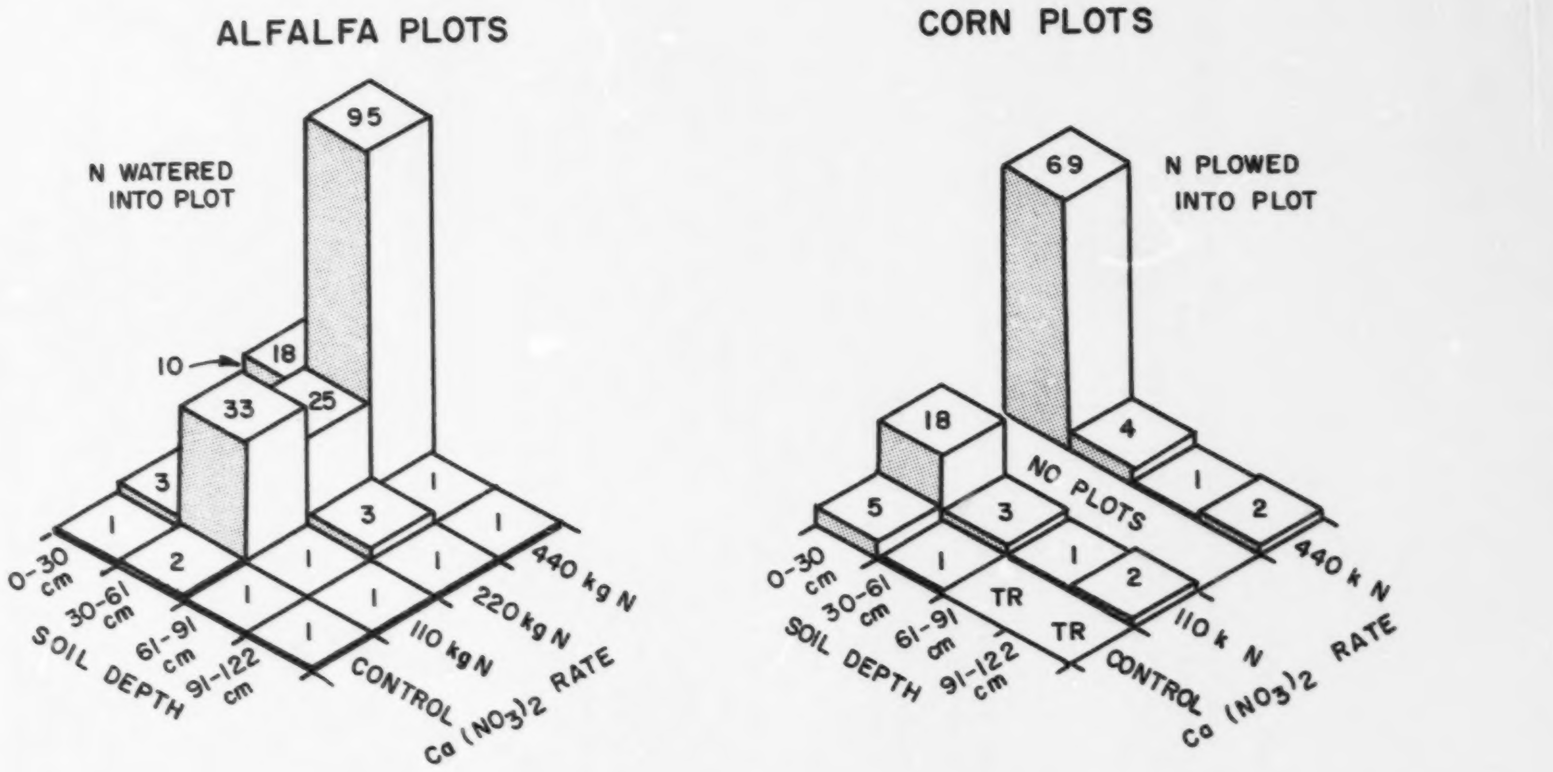


Figure 15. Nitrate-N in the soil samples from plots with varying amounts of $Ca(NO_3)_2$ fertilizer spread on the soil surface. Sampled June 28, 1972 shortly after the fertilizer was added.

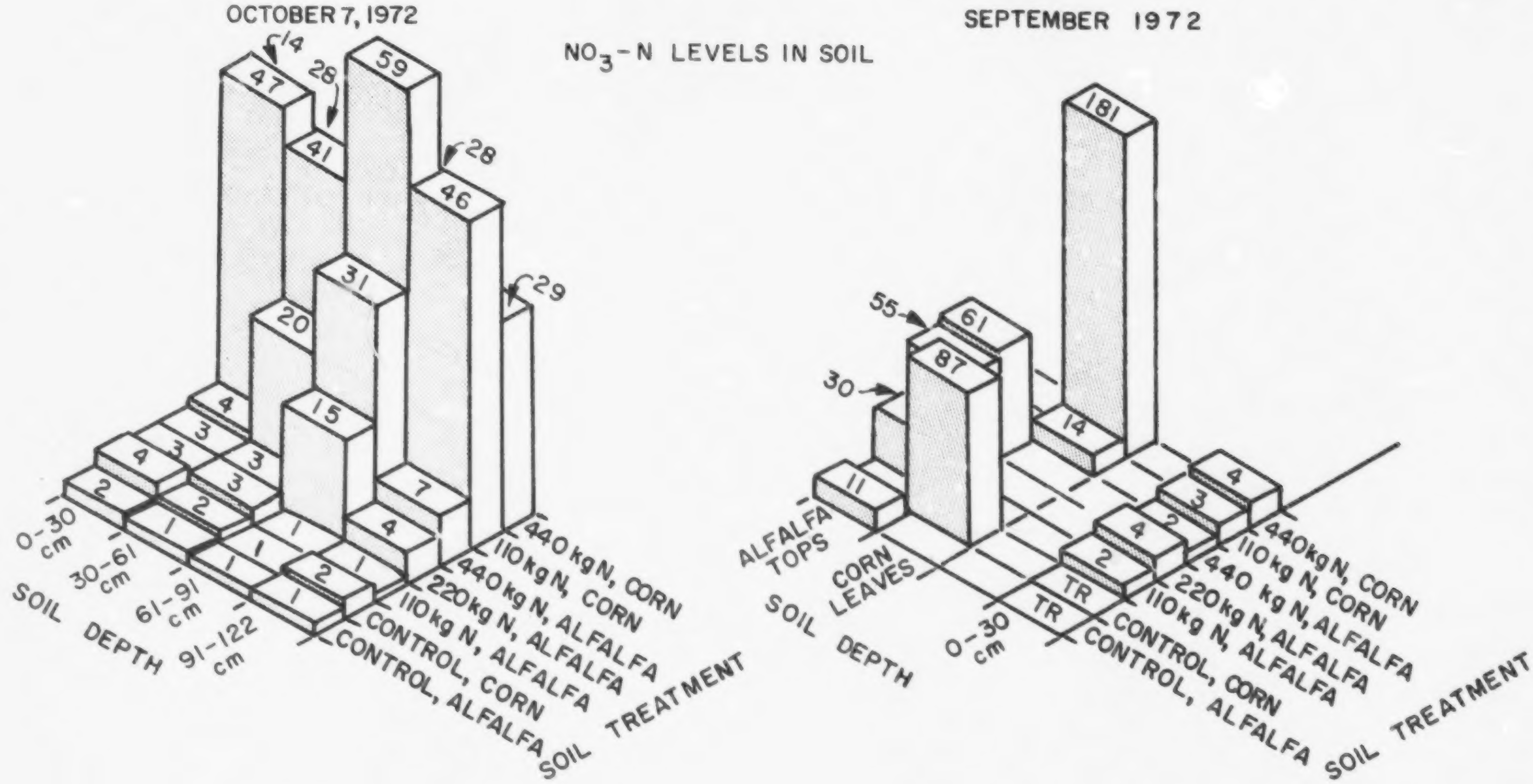


Figure 16. Nitrate-N in soil samples and in alfalfa and corn leaves as related to $Ca(NO_3)_2$ fertilizer rates in 1972. Data are ppm NO_3^--N.

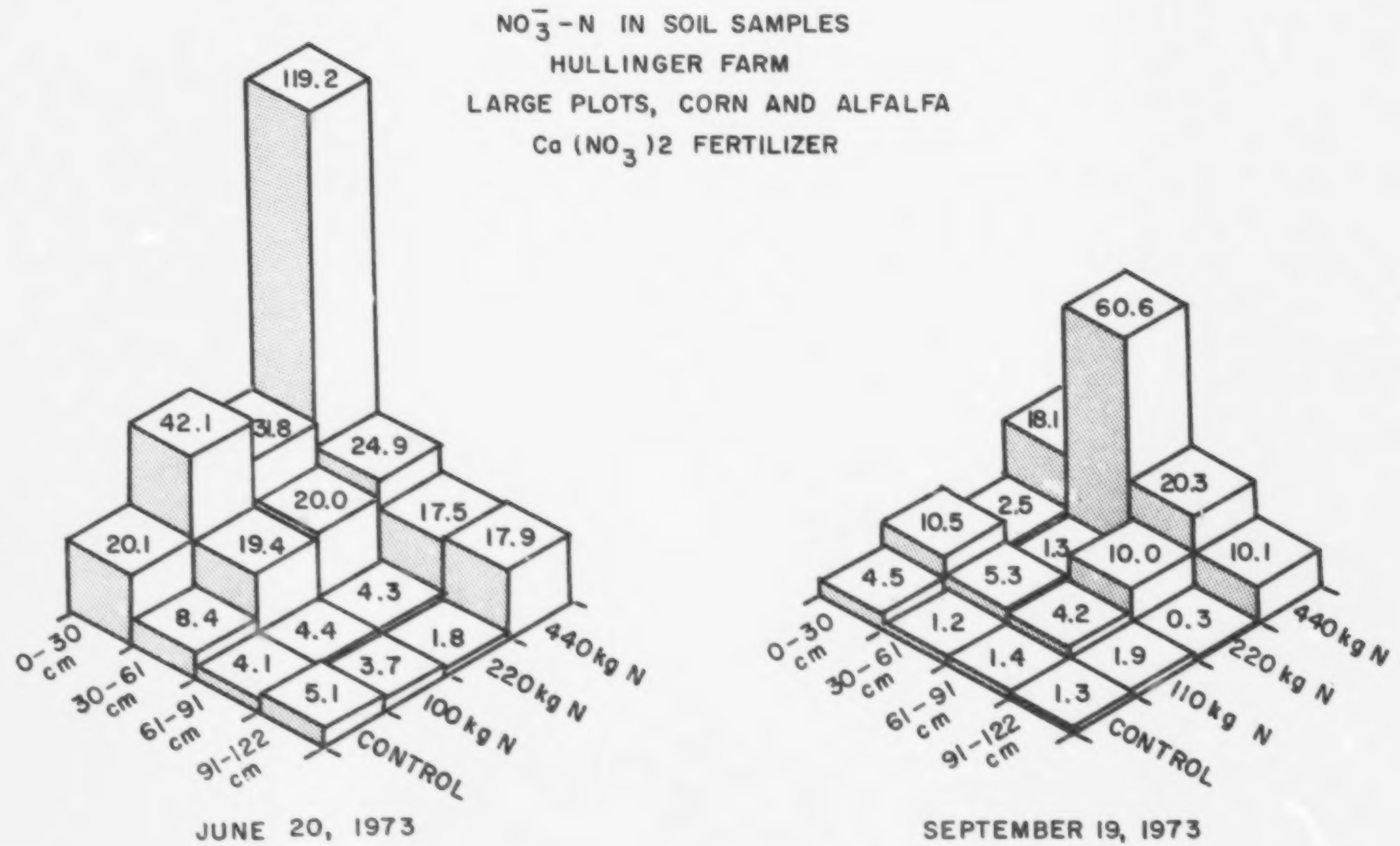


Figure 17. Nitrate-N (ppm) in soil profiles as a result of different applications of NH_4NO_3 fertilizer in 1973.

Table 21. SOIL NO_3-N CONTENTS IN SOIL SAMPLES TREATED WITH VARIOUS RATES OF NH_4NO_3 AND PLANTED TO CORN OR ALFALFA. HULLINGER FARM, VERNAL, UTAH, 1973.

NH_4NO_3 added	Soil Depth	NO_3-N in June 20 Sampling		NO_3-N in Sept. 19 Sampling	
		Alfalfa	Corn	Alfalfa	Corn
		cm	ppm	cm	ppm
Control	0-30	6	25	5	5
	30-61	5	9	1	1
	61-91	2	5	1	1
	91-122	0.4	6	0.5	1
110 kg/ha	0-30	14	51	3	12
	30-61	15	20	0.6	7
	61-91	1	5	1	5
	91-122	0.5	4	0.2	2
220 kg/ha	0-30	32		2	
	30-61	20		1	
	61-91	4		10	
	91-122	2		0.3	
440 kg/ha	0-30	56	140	5	22
	30-61	25	25	42	67
	61-91	5	20	11	24
	91-122	4	20	5	13

Table 22. NO_3-N LOSS FROM JUNE 20 TO SEPTEMBER 19, 1973.

NH_4NO_3 Added (kg/ha)[a]	Alfalfa Plots (kg/ha)[a]	Corn Plots (kg/ha)[a]
Control (0)	25	120
110	100	200
220	150	
440	100	320

[a] Reduction of ppm times 4 approximates kg/ha.

Ceramic cup solution analyses for 1973 verify the 1972 soil data that NO_3-N contents in alfalfa plots were lower than in corn plots (Figure 18 and Table B-16). When sampled periodically at 76 cm and 106 cm depths, almost no NO_3-N was obtained in the alfalfa plot soil extracts except from the 106 cm depth on plots having 440 kg/ha added. The values were between 36 and 59 ppm NO_3-N. In contrast, the corn plots had values between 37 and 124 ppm NO_3-N in extracts from the 440 kg/ha treatment at both the 76 and 106 cm depths. The 110 kg/ha rate plots and even the unfertilized control plots contained up to 21 ppm NO_3-N.

The drainage water NO_3-N content tends to verify soil analyses and soil extract contents of NO_3-N. Heavily fertilized corn plots (440 kg/ha) lost NO_3-N approaching 20 ppm during the first two months (June and July) but the loss dropped to less than 10 ppm in fall (Figure 19). The alfalfa plots lost less NO_3-N with drainage water values, commonly less than 5 ppm. The relatively high value of about 8 ppm as a mean value for NO_3-N in drainage water from the control plot is probably due to mixing of drainage water and lateral flow from outside the plots. One of the two control plots is within 50 m of a private home septic tank and drain field. NO_3-N values from the control plot furthest away from the home did not exceed 7 ppm and most were 3 to 5 ppm. Thus the only treatment that definitely caused increased NO_3-N in the drainage water was the 440 kg/ha level in corn.

Attempts to use NO_3-N measurements of drain effluent from the commercial fertilizer plots as a measure of NO_3-N movement through the root zone were not successful. Tables B-18 and B-19 of Appendix B give detailed results of the effluent concentration of NO_3-N. Note that one of the control drains (6N) had NO_3-N concentrations for 1973 which were nearly as great as for 5M and significantly greater than 4M, both of the latter receiving applications of fertilizer at the rate of 440 kg/ha. Nitrogen balances including the drain effluent were not attempted because of the above observation and the encroachment of groundwater from outside the farm boundaries. The plots were designed to include a dilution factor. The treatment area was about 30 m by 55 m (1650 m^2) while the surface area of water application was about 61 m by 70 m (4270 m^2). Thus the water percolating below the treated area to the water table should have been diluted by a factor of about 0.4 by the irrigation water percolating from untreated areas. The above procedure assumes no mixing with other groundwater and that all water flow in the drain originated from application of water to the surface 61 m by 70 m area. This discussion will not be pursued.

A very minor study of the effect of drain submergence on NO_3-N discharge was attempted. Drains 5N and 5M were submerged to a depth saturating the gravel envelope surrounding the drain pipe. The degree of the submergence obtained is indicated by water table depths of Table 7. Note that the average water table depth measured for plot 5N was less than any other north plot for both years of study, while plot 5M had an average water table depth essentially the same as other middle plots. This indicates that the natural drainage conditions

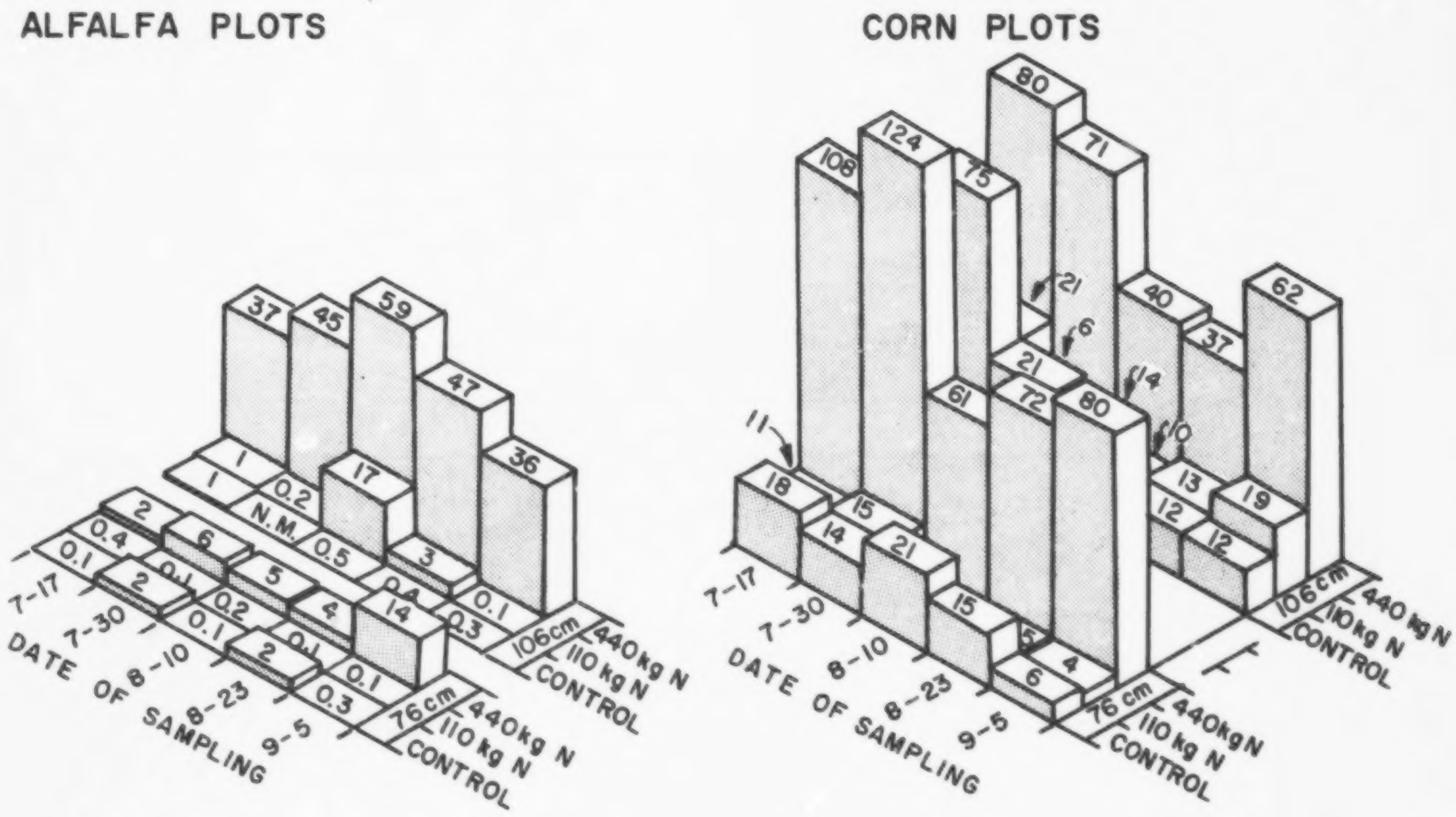


Figure 18. Nitrate-N (ppm) in ceramic sample extracts at 76 cm and 106 cm depths. $Ca(NO_3)_2$ fertilizer was added in 1972 and NH_4NO_3 fertilizer added in 1973.

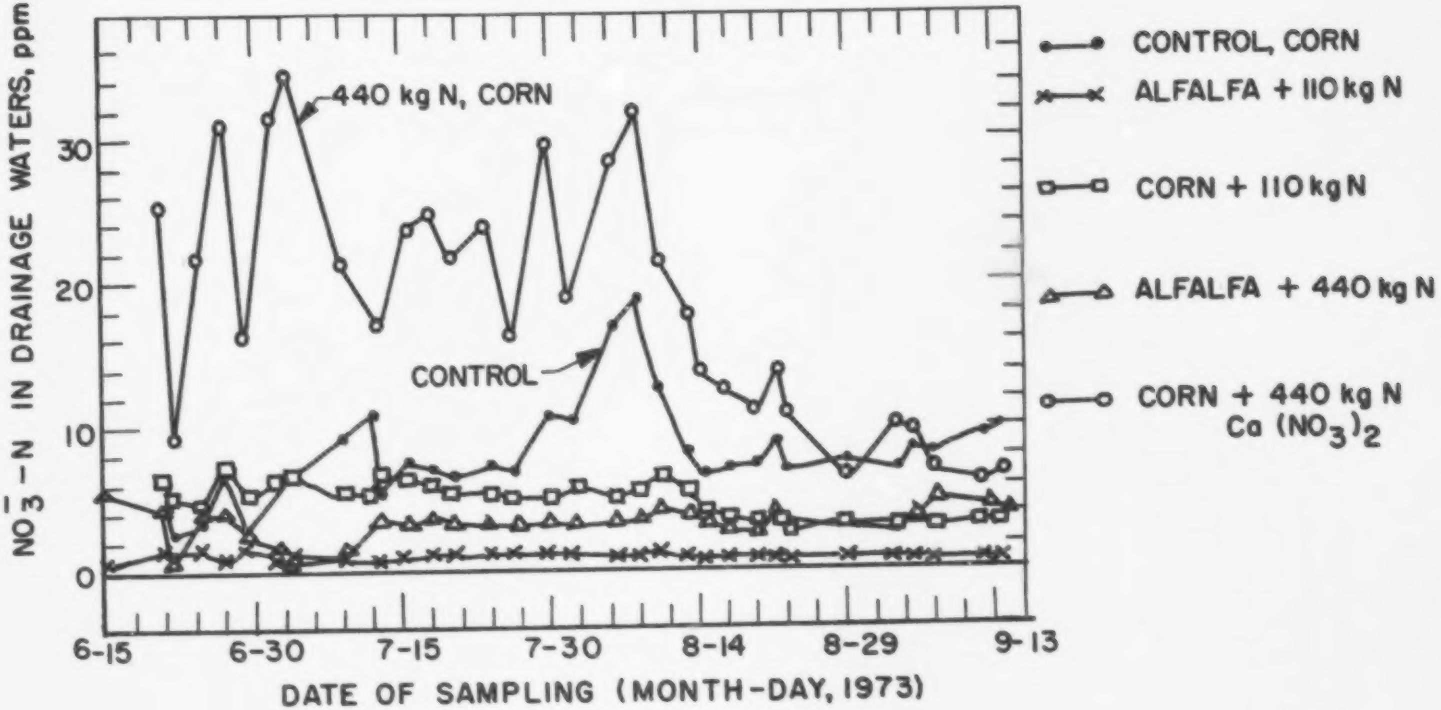


Figure 19. Nitrate-N content in drainage waters collected in 1973.

were such to not allow the water table under plot 5M to rise sufficient to effectively submerge the drain. The maximum submergence of the drains relative to a free flowing drain was 25 cm as indicated in Section IV, Methods.

Since drain 5N was the only drain which appeared to be submerged (i.e., water in the drain not in direct contact with outside air), for 1972 we could compare NO_3-N discharges of drains 5N and 5AN which had the same water and fertilizer application to overlying plots. Table B-18 shows significantly less concentration of NO_3-N in the effluent of drain 5N than drain 5AN. Table 4 shows that in 1972 plots 5A and 5AN received the same amount of irrigation water within 5%. Table B-19 also shows lower concentrations in the drain effluent of 5N compared to 5AN.

The tendency would be to conclude that submergence of the drain in the field would lower the discharge of NO_3-N. Again the encroachment of groundwater from outside the farm boundaries complicates the picture. For example, Table 5 shows that discharge of water from drain 5N was nearly 6 times that from 5AN for the 1972 season and more than 7 times that for drain 5AN for 1973.

Manure Plots

When high rates of manure are added to soils, the possibility exists of producing nitrates that leach into groundwaters. Whether or not nitrates move downward in the soil profile depends on the rate and amount of nitrates produced, the amount of water moving through the soil and the rate of denitrification. The rate of nitrate production should increase with heavier rates of manure or fertilizer application. The sandy clay loam-sandy loam textures of the farm soil are permeable and permit easy movement of water. The presence of a water table between 120 and 180 cm could allow for high water contents of the deeper subsoil which will favor denitrification. The denitrification process requires three major factors: (1) A source of nitrate to be reduced to N_2 and oxides of nitrogen, (2) oxidizable carbon as energy sources for the denitrifying bacteria, and (3) a lack of gaseous O_2. Manure added to the soil and a water table in the lower subsoil furnish these conditions. However, within the 122 cm depth studied, a condition of poor aeration was obvious in only a limited few layers of some profiles. This would suggest that nitrates may move readily within the profile to the depth of sampling.

The irrigation water applied to the manure plots can be obtained from Table 4. For 1972, block 9 shows irrigation of manure plots and some surrounding area. For 1973, the west part of block 9 shows the irrigation for the manure plots.

Nitrate is mobile in the soil used but is in low amounts except when added (Figure 20). Soil samples taken June 28, 1972, after the first manure was incorporated had almost no NO_3-N concentrations except in the 0 to 30 cm depth. See Table B-20, Appendix B for detailed data.

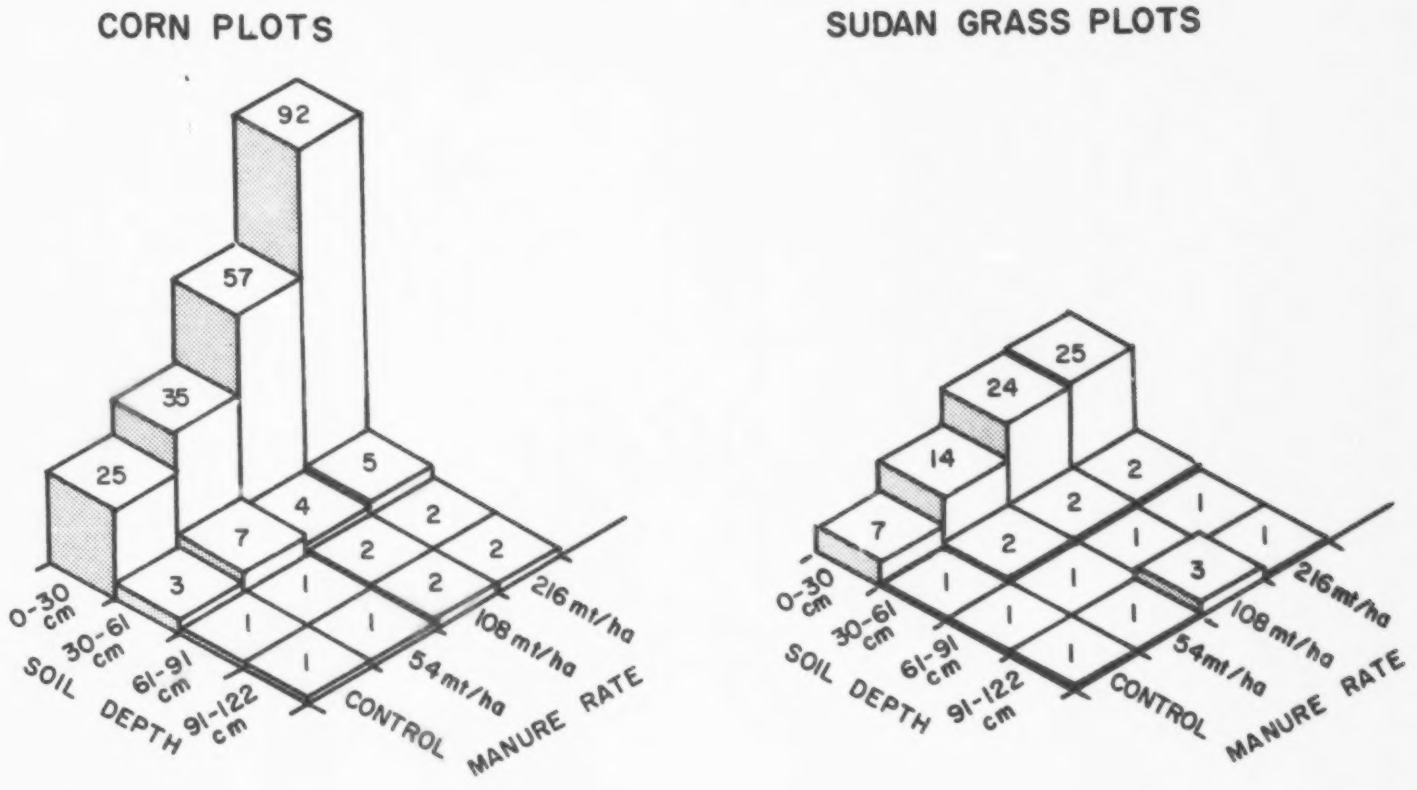


Figure 20. Nitrate-N (ppm) in soil profiles as influenced by manure rate applied. Sampled June 28, 1972. Manure applied May 1972.

The relatively high value of 25 ppm NO_3-N in the control plot planted to corn seems a little high. The average value is 10 to 12 ppm higher than four of the five replications because of a single high value of 72 in one plot. The general residual nitrate level before treatments is very low. Profile soil samples taken October 7, 1972, had NO_3-N dispersed throughout the 122 cm depth (See Figure 21). The NO_3-N values are still low; lower in the corn plots than in the sudan grass plots. Appreciable NO_3-N existed even to the 91-122 cm depth (34 ppm) on the heavy manure treatment. The NO_3-N in the control plots under both crops was low with a high value of 7 ppm. The moisture content of the soils was about 0.20 by volume fraction. Thus the NO_3-N in soil solution might be expected to be about 5 to 6 times greater than in a sample of the wetted soil, provided all NO_3 is in the water. Figure 22 shows NO_3 N contents of water samples taken by porous, ceramic cups (106 cm deep) to be about 4 to 10 times higher than soil sample values (See also Table B-21, Appendix B). In the unmanured plots (control) the NO_3-N increased to a maximum during the growing season and dropped off in the fall. At higher manure loading rates the NO_3-N maximums reached were higher, and did not show any consistent tapering-off in the fall.

The apparent inconsistency of high fall NO_3-N levels in corn in the soil solution but low values in the soil samples (Figures 21 and 22) when compared to the sudan grass data is not readily explained. The soil samples were taken three weeks after the last soil solution sample. Drainage losses or other modifications could have occurred.

The high of 76 ppm NO_3-N in the control plot under corn (Figure 22) may be partly a result of lateral water flow. Other evidences in the study indicate that some lateral flow does affect samples near the water table which may fluctuate at near the 106 cm depth of the sampler.

Nitrate concentrations in the soil profile remained high in the second year (1973) with generally the highest values in the surface 30 cm of soil of plots receiving the most manure (Figures 23 and 24 and Table B-22). In the June 20 sampling, the application of manure for the second consecutive year to one block of plots resulted in relatively little changes in NO_3-N contents in the soil except at the lowest rate (54 mt/ha). The 108 and 216 mt/ha rates for both blocks varied roughly from 20 to 100 ppm NO_3-N. This high NO_3-N in plots having manure added the previous year was not expected. The September 19, 1973 samples were a similar pattern, but did tend to have more NO_3-N in the soil when lower manure rates were applied two consecutive years than when only the 1972 application was made. It is interesting that the fall soil samples from planted control plots all had less than 10 ppm NO_3-N whereas those samples from plots with added manure still had NO_3-N levels mostly from 30 to 70 ppm.

The data of suction cup extracts agree with the NO_3-N distribution pattern found in 1973 (Figure 25 and Table B-23). Control plots had

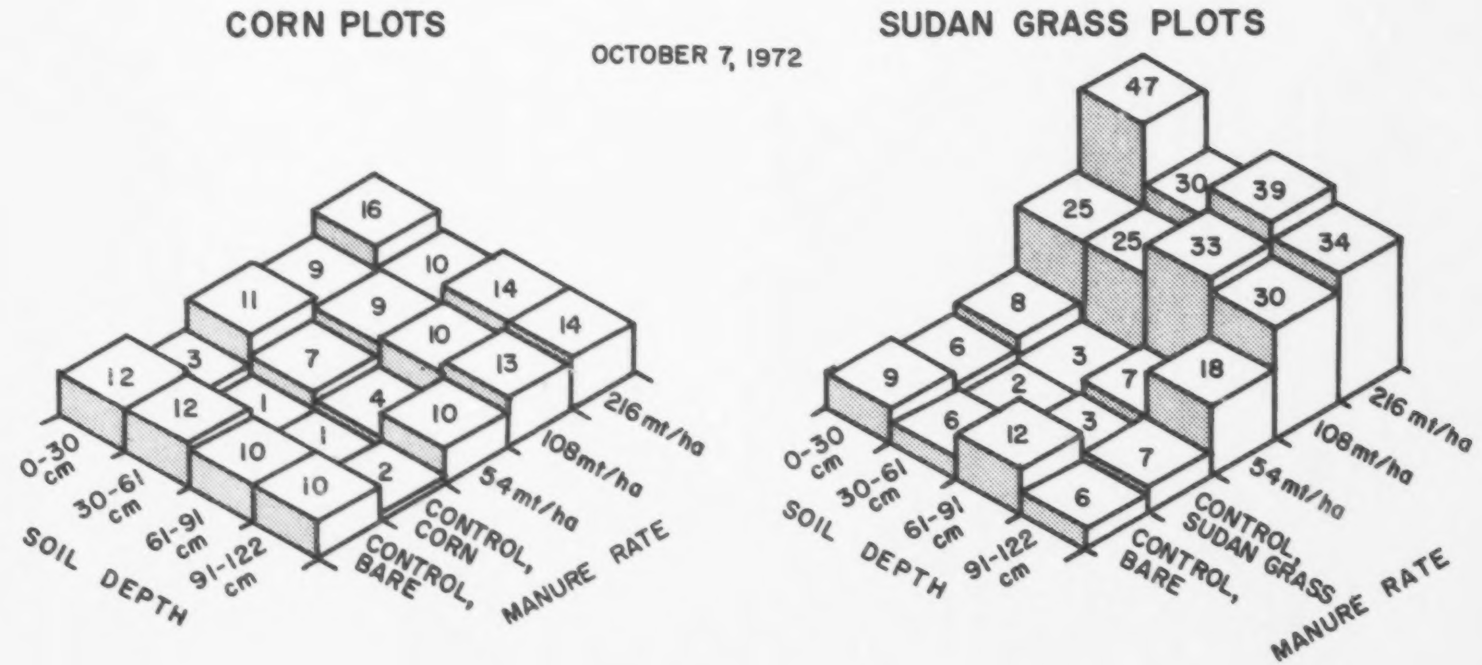


Figure 21. Nitrate-N (ppm) in soil profiles as influenced by manure rate applied. Sampled October 7, 1972.

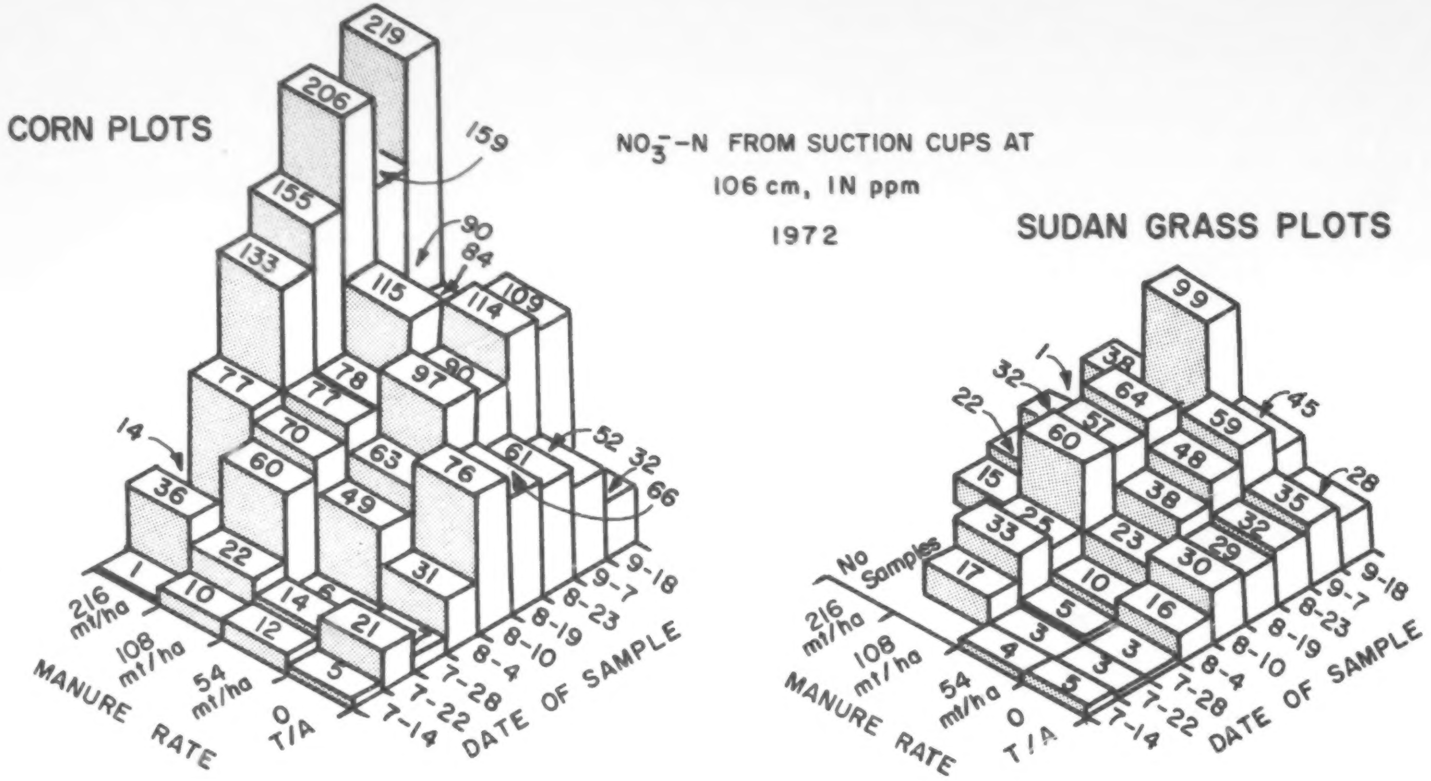


Figure 22. Nitrate-N (ppm) in soil extracts from ceramic samples at 106 cm depth in 1972 as influenced by manure treatment.

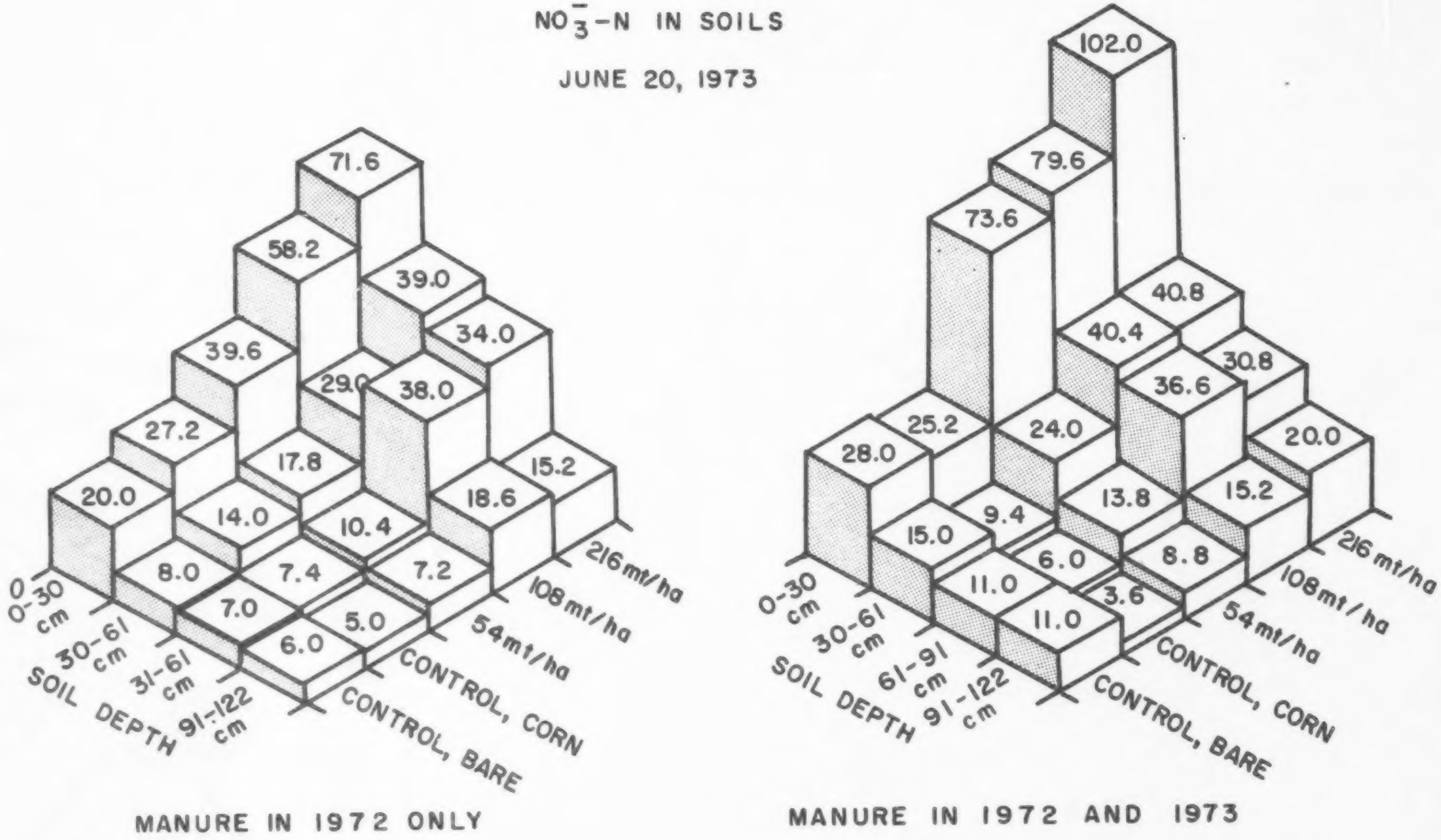
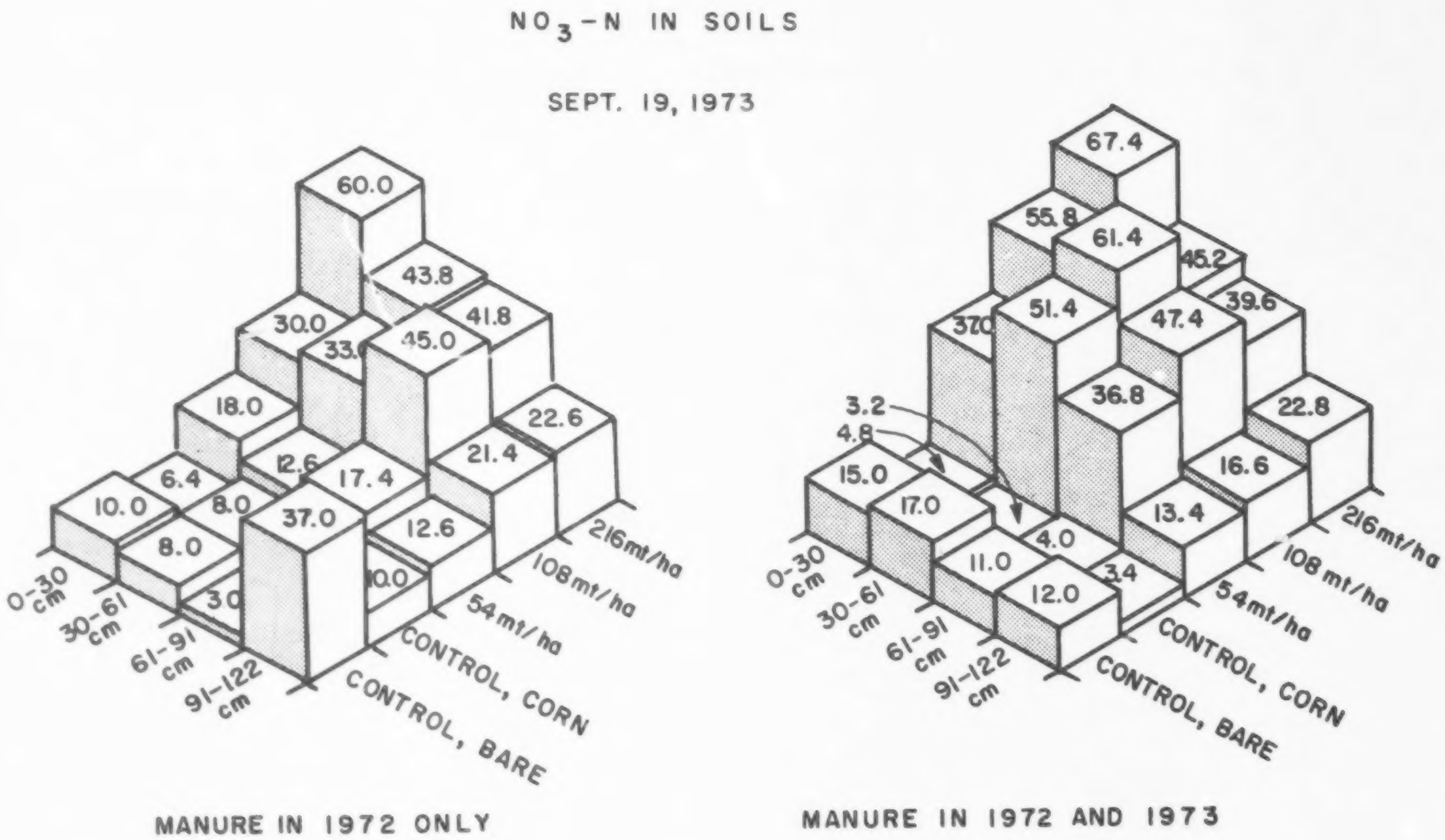


Figure 23. Nitrate-N (ppm) in soil profiles as influenced by manure treatment, sampled on June 20, 1973.

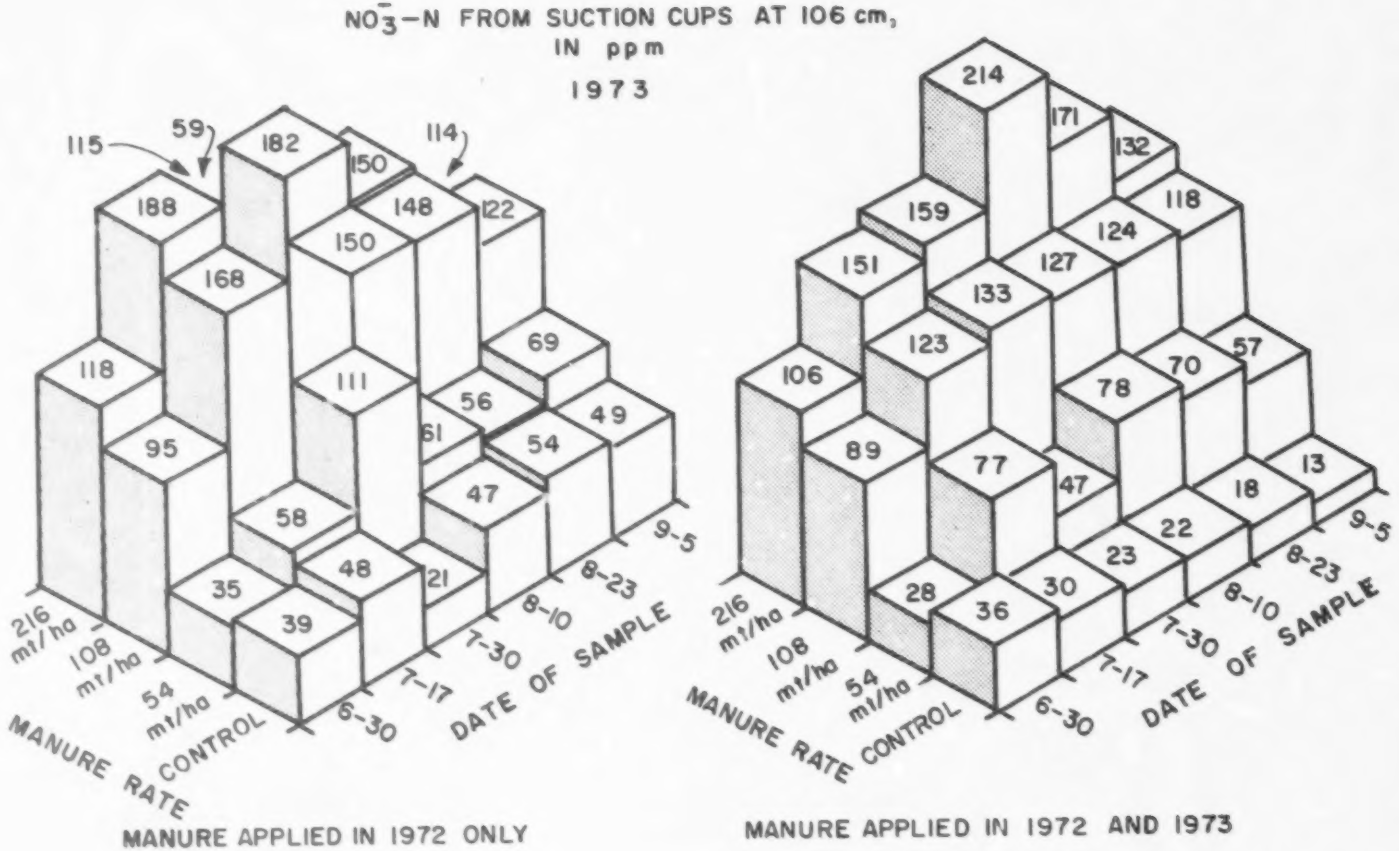

NO$_3$-N IN SOILS

SEPT. 19, 1973

MANURE IN 1972 ONLY

MANURE IN 1972 AND 1973

Figure 24. Nitrate-N (ppm) in soil profiles as influenced by manure treatment sampled on September 19, 1973.



MANURE APPLIED IN 1972 ONLY

MANURE APPLIED IN 1972 AND 1973

Figure 25. Nitrate-N (ppm) in soil extracts from ceramic samples at 106 cm depth in 1973 as influenced by manure treatment.

NO_3-N concentrations in the solution of 13 to 54 ppm whereas the plots with higher manure rates had solutions with many values over 150 ppm.

The plots with two consecutive years of manure applications had almost identical NO_3-N concentrations and concentration patterns as the plots in the second year which had only a single application of manure a year earlier. This is surprising. Researchers generally have predicted about 50 to 60 percent release of manure-N the first year and less than another 25 percent of the initial total N added in manure will be released during the second year. In this study so far, NO_3-N concentrations in soil samples or in extracts collected through installed suction cups has not appreciably lowered during the second year after manure application in spite of appreciable crop removal of N the first year. Even a second year's application of manure did not seem to build up the NO_3-N concentration levels noticeably (Figure 23).

Salt Content - Salt concentrations in the soil solution indicate that salt could become a problem if leaching was not done periodically when large quantities of manure are added to the soil. Figures 26 and 27 illustrate the extreme conductivities measured. The suction cup soil-water extracts collected in 1973 had over half the individual samples having EC values over 4 mmho/cm. Eight samples had values exceeding 8 mmho/cm. This is not surprising, since manure is known to contain appreciable quantities of soluble salts. It is obvious from the spread of points in Figure 26 and 27 that there is no close relationship between NO_3-N content and salinity. Obviously, heavy manure additions should increase both salt and NO_3-N contents, so a noticeable correlation is apparent and real, but not adequate for predictive purposes. See Table B-24 and B-25 in Appendix B for details of EC measurements on water samples extracted from soils of the manure plots.

This increase in salt is more obvious by referring to values in Table 23 for the samples collected in the 1972 summer and to Figures 26 and 27 for 1973 samples. In 1972, conductivities mostly ranged between 3 and 4 mmho/cm except a few values near 5 mmho/cm where larger manure applications were made. In 1973 samples increased in conductivity almost 1 mmho/cm over 1972 values for plots receiving the larger amounts of manure. The 1973 plots with 216 mt/ha of manure had an average conductivity of 6.0 mmho/cm compared to 4.5 mmho/cm for those plots in 1972. This value of 6.0 mmho/cm was the same for both blocks of manure plots, one with only 1972 manure application and the other with applications in both 1972 and 1973. This is surprising since sprinkler irrigation was intended to be heavy enough to remove water and thus soluble ions downward in the profile. Since these conductivity values are for solutions obtained at 106 cm deep, perhaps sufficient salt was leached to this depth in 1972 even though it was also present in the soil profile at shallower depths.

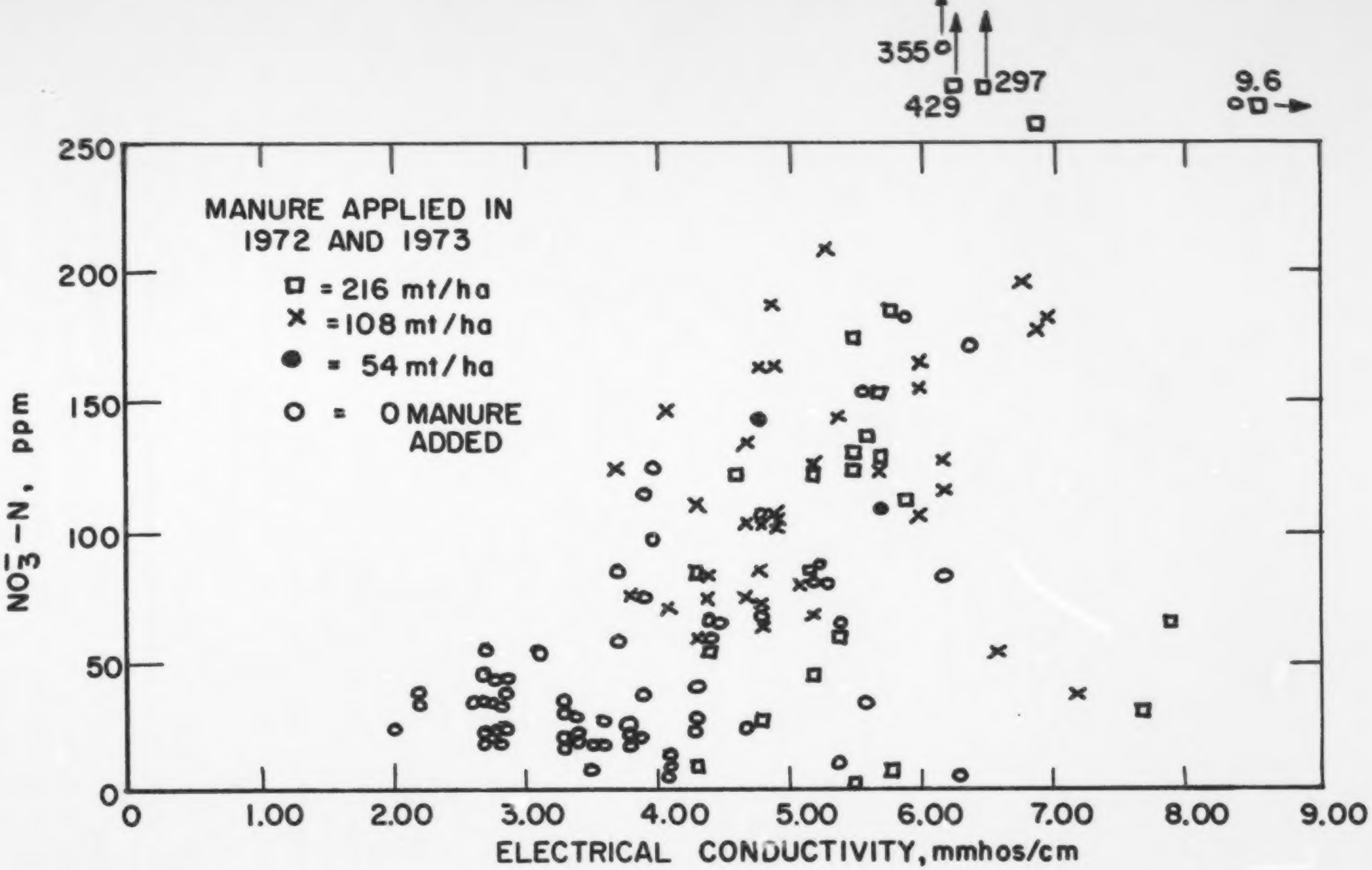


Figure 26. Comparison of electrical conductivity versus NO_3^--N collected from ceramic samplers from manure plots in both 1972 and 1973.

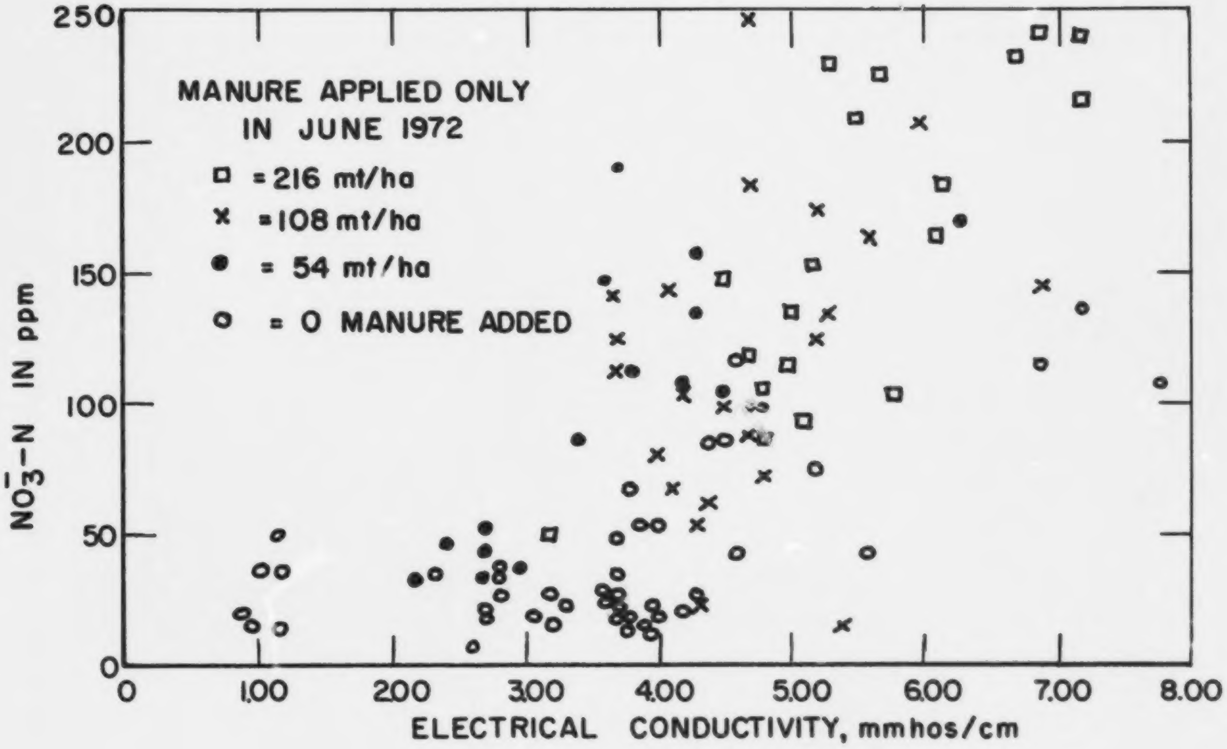


Figure 27. Comparison of electrical conductivity versus NO_3^--N collected from ceramic samplers from manure plots treated in 1972.

Table 23. ELECTRICAL CONDUCTIVITY (EC) OF SOIL SOLUTIONS TAKEN USING POROUS CERAMIC CUPS INSTALLED AT 106 cm DEPTHS. HULLINGER FARM, VERNAL, UTAH, 1972.

		Crop Grown	
Manure Rate Dry Weight	Date of Sample	Sudan Grass (mmho/cm)	Corn (mmho/cm)
Control	7-14	3.1[a]	3.6[a]
	7-22	2.6	2.8
	7-28	3.6[a]	3.4
	8-4	4.1[a]	3.4[a]
	8-10	4.1	3.9
	8-19	4.1	3.8
	8-23	3.7	4.1
	9-7	4.1	4.0
	9-18	4.1	4.1
54 mt/ha	7-14	3.7	3.8
	7-22	3.4	3.9
	7-28	4.1	3.0[a]
	8-4	4.2[a]	3.4
	8-10	6.6[a]	4.0
	8-19	4.6	4.0
	8-23	4.8	4.2
	9-7	4.8	4.1
	9-18	4.9	4.1
108 mt/ha	7-14	4.8[a]	2.7[a]
	7-22	4.0	2.8
	7-28	4.1	4.1[a]
	8-4	4.9[a]	3.6
	8-10	4.1	4.0
	8-19	4.0	4.4
	8-23	4.2	5.1[a]
	9-7		3.9[a]
	9-18	5.5	5.2[a]
216 mt/ha	7-14		2.0[a]
	7-22	3.9[a]	2.9
	7-28	3.9[a]	3.9[a]
	8-4		4.7
	8-10	4.3	4.6
	8-19	4.5	4.9
	8-23	4.6	6.2
	9-7	5.4[a]	5.0[a]
	9-18	4.6	6.2

[a] Solution extracts from only two or fewer reps could be obtained for analysis.

Barrel Lysimeters

The data for NO_3-N in the barrels in 1972 are shown in Table 24 (see also Table B-26). High irrigation rates were used so that all of the barrels, except the four drained barrels, were waterlogged sufficiently that corn growth was severely stunted. The barrels received irrigation water by the same schedule as the manure plots discussed in the foregoing.

Higher NO_3-N values were measured under commercial fertilizer applications than the manure treatments. There were much higher values of nitrate measured in the 440 Kg/ha $Ca(NO_3)_2$ barrels than 100 Kg/ha and the 110 Kg/ha rate was higher than the check treatment. The barrels having drains with 440 Kg/ha - $Ca(NO_3)_2$ had slightly higher nitrate values than the waterlogged barrels. Where $Ca(NO_3)_2$ fertilizer was used, denitrification seems to have occurred in the early part of August in the undrained and drained barrels but the NO_3-N level seems to remain constant after that time. The drained barrels may have had leaching losses. Barrels with higher fertilizer additions did not decrease in NO_3-N levels to the NO_3-N levels obtained in barrels with lower fertilizer rates. This suggests that the NO_3-N reduction was limited by conditions other than NO_3-N content (possibly by organic carbon availability in the deeper depths).

A very different effect is observed in the manure application data (Table 24). The large source of readily soluble and mobile organic carbon permitted maximum denitrification to occur in the waterlogged barrels. The NO_3-N decreased with increasing manure application levels. Soils with rates of 216 mt/ha added had less than a third as much NO_3-N as when only 54 mt/ha was added. In contrast, the drained soils having 216 mt/ha of manure added, apparently had less denitrification losses and had high levels of NO_3-N. The ratio of NO_3-N in the drained soil to NO_3-N in waterlogged soil by weekly intervals was 1.2, 1.1, 1.5, 5.3, 7.6, 24.3, 24.3, and 7.0. Early NO_3-N levels before waterlogging developed extensively might be expected to be similar. The higher the rate of manure added, the lower the soluble NO_3-N extracted in early weeks. This is probably a result of conversion to soluble NO_3^- by organic synthesis.

At the beginning of the 1973 season, drains were installed in all barrels. Also there was much less irrigation applied in 1973 than 1972. The barrels had a much lower water content, were not waterlogged and had better corn growth. However, the soil water content was so low that it was impossible to get soil water samples from the ceramic samplers except in a few cases (Table B-27 Appendix B). The available data show very little NO_3-N in the manure treated barrels that had been waterlogged in 1972. This indicates that denitrification had been nearly complete under the waterlogged conditions of 1972. No new additions of nitrogen, either as commercial fertilizer or manure, were made to the barrels in 1973. Table B-28 in Appendix B gives results of EC measurements on water samples from barrels.

Table 24. NO_3-N MEASUREMENTS MADE IN THE BARRELS.[a]

(ppm)

		$Ca(NO_3)_2$ kg/ha			Manure mt/ha			
Date	Check	110	440	440	54	108	216	216D
----1972----								
7-13-72	117	65	283	--	75	59	24	--
7-22	116	167	198	44	81	58	33	38
7-28	103	308	292	403	102	67	34	38
8-1	73	174	380	330	92	83	27	40
8-10	99	123	256	620	53	76	26	138
8-18	87	105	306	410	80	71	21	159
8-23	80	110	312	158	69	63	15	364
9-6	69	136	273	--	63	54	10	--
9-20	43	84	225	328	39	32	1	243
Average 1972	87	141	280	328	73	62	21	146
----1973----								
6-21-73	11	23	224	--	10	5	1	280
6-30	20	49	185	--	14	6	1	301
7-16	17	22	158	--	17	1	--	226
7-30	27	--	--	--	13	--	1	--
8-8	--	--	169	--	--	--	28	183
8-23	--	1	55	--	--	--	54	44
9-5	--	7	--	--	--	--	27	--
Average 1973	19	20	158	--	14	4	19	207

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[a] Samples were taken at about 70 cm from the soil surface from ceramic samplers. D refers to barrels that had drains. The barrels were planted to corn and treated only in 1972.

Yields

Only limited yield data were taken from the large plots (0.17 hectare) of this study because it was apparent that there were generally little differences in yield due to treatment. In 1972, corn was planted so late that it did not mature and was harvested for silage only. In 1973, corn was planted and matured normally which resulted in grain yields as shown in Table 25. The data indicate no influence of treatment on yields.

Table 26 shows the yields from the manure plots in 1972 and 1973. The data show a small increase in yield as the manure rate increased to 108 mt/ha. The yields of both corn and sudan grass where treatments were imposed the same year were depressed by the high manure rate. However, there was apparently a beneficial effect of the high manure treatment the following year. Thus, these data would indicate no harmful effect on yield of manure treatments up to about 100 mt/ha of manure.

Summary

In many areas of the western United States, irrigation practices significantly influence the quantity and quality of irrigation return flow. In the Colorado River Basin, salinity (total dissolved solids) is recognized as the most serious water quality problem. The research covered by this report involved study of the degree of control of return flow which is possible through management on the farm of irrigation, drainage, and fertilizer application practices. The project included field, laboratory and computer modeling work.

Most of the field work was conducted on the Hullinger Farm near Vernal, Utah. The farm had a solid-set sprinkler system and a subsurface drainage system. Large plots (30 by 55 m) were treated with applications of nitrogen fertilizer (0, 110, and 440 kg/ha). Different irrigation treatments were applied to these plots and salt and nitrate movements were studied. Both alfalfa and corn were grown.

Effects of irrigation management on salt movements were evaluated from measurements of EC of the drain effluent and the soil solution above the water table. In 1972, the corn was irrigated to insure downward movement of water through the root zone. Application rates were used on the corn of 1.1 and 1.5 times ET which was measured by lysimeters containing alfalfa. In 1973 the corn plots were irrigated whenever the soil moisture decreased to a predetermined level. The total depth of irrigation water was much less in 1973 than 1972. Although the average EC of irrigation water and drain effluent for any drain was essentially the same for 1972 and 1973, the total salt discharged was greater for 1973. This is because the drain flow was greater in 1973 than 1972. This greater drain flow occurred even with considerably less application of irrigation water on the farm. Measurements of groundwater gradients confirmed that groundwater moved to the drains from outside the farm

Table 25. GRAIN YIELDS FROM CORN IN 1973 AS INFLUENCED BY COMMERCIAL FERTILIZER TREATMENT.

Plot Treatment	Corn Grain Yield (17% Moisture) kg/ha
5N	6840
5M	7150
5S	7150
5AN	7150
5AM	7460
5AS	7150
6N, 6M, 6S	6840

Table 26. YIELDS OF CORN AND SUDAN GRASS IN 1972 AND CORN IN 1973 ON THE MANURE PLOTS. YIELDS ARE IN FRESH WEIGHTS.

	Manure Treatment			
	Check	54	108 (mt/ha)	216
1972 Corn	47.1	48.1	50.2	46.5
1972 Sudan Grass	49.9	53.8	51.2	44.6
1973 Corn (retreated)	54.3	52.9	56.6	42.9
1973 Corn	46.8	55.2	55.4	56.6

boundaries. The drain discharge was relatively insensitive to irrigation management on the farm and depended upon practices of farmers over a much larger area. Thus any irrigation management plan for return flow quality control must include the major part of a hydrologic unit in order to be successful.

In general, the higher values of drain effluent EC were associated with infrequent small flows where the average water table was deeper. This result indicates salt storage above the water table. It is very likely that storage has been going on for long periods of time and is not directly a result of irrigation management practiced since research work began on the Hullinger farm (1970).

The EC of water samples collected from ceramic cups above the water table was higher than for drain effluent. Thus, the general groundwater was of better quality than the soil profile discharge from the farm. Water table depth appears to be an important factor on storage of salt in the soil profile.

The total seasonal salt discharge was directly related to the quantity of water discharged by the drains. Therefore management of water is the key to successful return flow quality management. Any control plan which will reduce total discharge of water will probably also reduce total discharge of salts, at least over the short term. The period of effectiveness of such a plan is difficult to ascertain.

Field trials for detailed study of salt movements were conducted at three sites (Vernal, Farmington and Logan) having different soils. Water of various qualities (EC ranging from about 1 to 10 mmho/cm) was added to small areas and its movement through the soil profile was monitored. Addition of large amounts of water to the soil surface had little effect on the soil solution EC. Results indicate large "buffering" within the soil suggesting that considerable precipitation and solution of salts were occurring. Monitoring soil solution EC with vertical four-probe, horizontal four-probe, and samples extracted through ceramic cups showed the three methods to give reasonably comparable results.

Laboratory studies on the soil from the Hullinger farm also indicated the existence of high "buffering" capacity. This soil contains a complex mixture of salts having different source strengths and solubilities. Large quantities of relatively low solubility salts were shown to exist.

Computer models for simultaneous salt and moisture flow were modified to better describe salt movements. Diffusion and dispersion were included. Numerical procedures were modified to eliminate "numerical dispersion." Root growth and seasonal changes in rooting depth with time were included. Methods were developed to estimate crop yield based upon relative transpiration. The model was modified to allow for variation of the relative proportion of potential transpiration to potential evapotranspiration over the season. Variations in evapotranspiration during a 24-hour day were included. Predictions of relative yield made for many different management possibilities indicated that yield decreases would not occur until several years later because of slow salt buildup. The predictions were highly dependent on the root depth because of the presence of water. Several management possibilities that allow salt storage in the profile for several years (no leaching) were shown with little yield decrease. However, some leaching will eventually be needed.

Nitrate movements were studied beneath large plots (30 by 55 m) which were treated with applications of commercial fertilizer, smaller plots (6 by 12 m) treated with dairy manure, and barrel lysimeters treated with both commercial fertilizer and manure. Soil samples from the large plots indicated more NO_3-N in the corn plots than the alfalfa plots at the end of each season. Samples withdrawn from ceramic cups in the soil profile also showed this result.

Results of NO_3-N measurements from tile drain effluent were masked by the encroachment of groundwater from outside the farm boundaries. One of the control drains (overlying plot received no application of nitrate) had NO_3-N concentrations as great or greater than drains beneath two of the plots receiving 440 kg/ha application of fertilizer.

One drain was successfully submerged so that the water table was always at or above the top of the gravel envelope during the irrigation season. The NO_3-N concentration of effluent from this drain was significantly lower than for the drain receiving the same fertilizer application but flowing freely and having air within the drain pipe.

Soil samples from the manure plots indicated that prior to application of manure, the residual nitrate level was low. In 1972 plots were treated with manure and duplicate sets of plots were planted to corn and sudan grass. In 1973, those plots with sudan grass the previous year received additional treatments of manure while those planted to corn the previous year received no additional manure. Corn was used on all cropped plots in 1973. During 1973, the plots with two consecutive years of manure application had almost identical NO_3-N concentrations and distributions in the profile as the plots receiving only one application of manure. Concentrations of NO_3-N did not drop appreciably during the second year after manure application in spite of appreciable crop removal of N the first year. Even a second year's application of manure did not buildup the NO_3-N concentrations noticeably.

Salt concentrations in soil solution extracted from the manure plots indicated that leaching should be done periodically when large quantities of manure are added to the soil. The yields of both corn and sudan grass where treatments were imposed the same year were depressed by the high manure rate. However, there apparently was a beneficial effect of the high manure treatment the following year.

Thus, the results indicated no harmful effect on yield of manure treatments up to about 100 mt/ha.

In 1972 the barrel lysimeters without drains were waterlogged sufficiently to severely stunt growth of corn. The NO_3-N concentrations extracted from the bottom of the barrels were higher for the commercial fertilizer treatments than the manure treatments. Denitrification was probably limited by supply of carbon in the commercial fertilizer treated barrels while the manure may have supplied carbon for more complete denitrification.

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SECTION VIII

APPENDICES

A. FORTRAN Listing of Computer Model

B. Field Data

APPENDIX A

FORTRAN Listing of Computer Model

```
SOWATT*STUFILE.MAIN
C     ML= NUMBER OF JOBS TO BE RUN
C     MLM=1 IF SAME BASIC SOIL DATA IS USED FOR ALL JOBS
C     MLM=0 IF SOIL IS DIFFERENT FOR DIFFERENT JOBS
C     DATE = A 70 SPACE TITLE CARD
C     K= NUMBER OF DEPTH INCREMENTS
C     KK=K+1= THE NUMBER OF DEPTH BOUNDARIES
C     MP= NUMBER OF CALCULATIONS BETWEEN PLOT ROUTINES
C     IFR= NUMBER OF BOUNDARY CONDITIONS*2.
C     NB= NUMBER OF DEPTH INCREMENTS TO USE IN COMPUTATION - USUALLY K
C     ND= NUMBER OF ENTRIES IN THE WATER CONTENT- POTENTIAL TABLE NOTE-
C     YOU NEED ENTRIES FOR WATER CONTENT OF ZERO AND ONE ABOVE WATH
C     KI,KP,KA CONTROL OUTPUT  EX. - KI=1 GIVES RESULTS AT BOUNDARY CONDITIONS
C                              EX. - KP=2 GIVES GRAPHS AT BOUNDARY CONDITIONS
C
C     IPTPRT,KS GIVE SPECIAL OUTPUT FOR PROGRAM CHECKING
C     ALAMBA,DIFO,DIFA,DIFB ARE SALT LOOP PARAMETERS
C     E= HYDRAULIC CONDUCTIVITY ARRAY
C     KILL= 1 SUPPRESSES PRINTING OF INPUT DATA
C     V= BOUNDARY CONDITION ARRAY GIVEN AS FLUX,TIME TO END,FLUX,TIME TO
C     END,ETC. + FLUX IS IRRIGATION OR RAIN, - FLUX IS ET POTENTIAL
C     SF= BOUNDARY CONDITION ARRAY FOR SALT CONCENTRATION OF WATER
C     DD= DEPTH INCREMENT ARRAY
C     RDFSAV= ROOT DENSITY FUNCTION ARRAY AS DECIMAL FRACTION OF ROOTS PER DEPTH
C     P= MATRIC POTENTIAL ARRAY
C     MLX= DATA READIN OPTIONS FOR MULTIPLE JOB RUNS
C     SMAX= SCALER FOR SALT CONTENT IN PLOT SUBROUTINE
C     RDFDAY= NUMBER OF DAYS FOR DEVELOPMENT OF MATURE ROOT PROFILE
C     RDFDEL= NUMBER OF COMPUTATION INCREMENTS IN ROOT GROWTH LOOP
C     DDROOT= DEPTH OF MATURE ROOT PROFILE - USUALLY DD(KK)
C     SALTA= MULTIPLIER FOR SALT CONTENT VALUES TO CHANGE UNITS
C     ESTART= DAYS FROM TIME TO START OF COVER GROWTH
C     ESTOP= DAYS FROM TIME TO ACHIEVEMENT OF MAX. EFFECTIVE COVER GROWTH
C     AK1= DECIMAL FRACTION - TRANSPIRATION/EVAPOTRANSPIRATION
C     AK2= DECIMAL FRACTION OF T/ET WHEN E.NE.EPCT
C     DELT IS TIME INCREMENT TO START WITH AND LOWEST TO USE
C     COND IS  LARGEST WATERCONTENT CHANGE ALLOWED EACH COMPUTATION
C     DELW IS WATER CONTENT DIFFERENCE CORRESPONDING TO TABLE INCREMENTS
C     TIME IS CUMULATIVE TIME AT START OF COMPUTATION
C     TT IS 1.0 FOR LAASONEN AND 0.5 FOR CRANK NICHOLSON
C     CUMT IS TIME AT END OF COMPUTATION
C     RRES= ROOT RESISTANCE
C     HDRY IS PRESSURE OF LOWEST POSSIBLE WATER CONTENT
C     HWET IS PRESSURE OF HIGHEST POSSIBLE WATER CONTENT
C     WATL IS LOWEST POSSIBLE WATER CONTENT
C     WATH IS HIGHEST POSSIBLE WATER CONTENT
C     HLOW IS THE MINIMUM ROOT POTENTIAL ALLOWED
C     HHI IS THE MAXIMUM  ROOT POTENTIAL ALLOWED
C     PP REPRESENTS PLANT UPTAKE ADDITIONS
C     CWF=CUMULATIVE WATER FLOW
C     SCH= SALT FLOW ACROSS LOWER BOUNDARY
C     WFROD AND WFDD ARE SURFACE WATER FLOW RATES COMPUTED TWO WAYS
C     CUMS=CUMULATIVE WATER FLOW AT THE SURFACE
C     CUMB= CUMULATIVE WATER FLOW AT THE BOTTOM
C     SALT= TOTAL SALT IN THE PROFILE
C     HROOT= ROOT WATER POTENTIAL
C     H IS WATER PRESSURE AS A FUNCTION OF DEPTH  BEGINNING AT TOP
C     W IS WATER CONTENT  AS A FUNCTION OF DEPTH  BEGINNING AT TOP
```

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```
      C     ETPL IS THE POTENTIAL TRANSPIRATION,ALWAYS NEGATIVE
      C     ET IS THE POTENTIAL EVAPOTRANSPIRATION,ALWAYS NEGATIVE
      C******DD,H,G,Y,W,RDF,A,SF,SS,SD,ARRAYS ARE OF SAME DIMENSIONS AT LEAST=KK
      C******SF,TET,V ARRAYS ARE OF SAME DIMENSIONS AT LEAST=IER
      C******P,D,T,ARE OF EQUAL DIMENSIONS,=ND AT MOST
      C-----TAA=1, FOR ZERO FLUX AT BOTTOM,TAA=0 FOR H(KK) CONSTANT          A   5
      C-----K IS NO. OF DELX INCREMENTS,MM NO. OF TIMES H&W PRINTED,KIT NO.OF  A  12
            DIMENSION RDFSAV(25),ROOT(25)
            DIMENSION DD(25),H(25),G(25),Y(25),W(25),RDF(25),A(25),SF(25)
            DIMENSION SF(65),TET(65),V(35)
            DIMENSION SS(25),SD(25),C(25),B(25),F(25)
            DIMENSION P(125),D(125),E(125),T(125),DATE(70)
            READ(5,269)ML,MLM
            LMM=0
       13   READ(5,3)DATE
            READ(5,268)K,MM,IER,NB,ND,KI,KP,KA,IRTPRT,KILL,K5
            KK=K+1
            READ(5,271)ALAMBA,DIFO,DIFA,DIFB,DELW,CONH
            IP=IER/2
            READ 271, (V(I),I=1,IER)
            READ 271,(SF(I),I=1,IR)
            READ 271,(DD(I),I=1,KK)
            READ(5,271)(RDFSAV(I),I=1,KK)
            READ(5,271)(P(I),I=1,ND)
            READ(5,271)(E(I),I=1,ND)
            IF(KILL.EQ.1)GO TO 1500
            WRITE(6,277)
            WRITE (6,268) K,MM,IER,NB,ND,KI,KP,KA
      1500  T(1)=0.
            D(1)=(E(1)*(P(2)-P(1)))
            DO 16  I=2,ND
            D(I)=E(I)*(P(I)-P(I-1))+D(I-1)
       16   T(I)=DELW+T(I-1)
            IF(KILL.EQ.1)GO TO 14
            WRITE(6,280)
            NE=ND/2
            DO 28 I=1,NE
       28   WRITE(6,275)T(I),P(I),E(I),D(I),T(NE+I),P(NE+I),E(NE+I),D(NE+I)
       14   IF(LMM.EQ.0) GO TO 23
            IF(ML.EQ.1.OR.MLM.EQ.0) GO TO 23
            READ(5,269) MLX,KILL
            READ(5,3)DATE
            IF(MLX.EQ.1.OR.MLX.EQ.4)READ(5,271)(V(I),I=1,IER)
            IF(MLX.EQ.2.OR.MLX.EQ.4)READ(5,271)(SF(I),I=1,IP)
            IF(MLX.EQ.3.OR.MLX.EQ.4)READ(5,271)(RDFSAV(I),I=1,KK)
       23   LMM=LMM+1                                                     00079000
            KC=1                                                          00079010
            READ 271, (W(I),I=1,KK)
            READ 271, (SE(I),I=1,KK)
            READ 271, DETT,CONQ,TAA,TIME,TT,CUMT,RRFS
            READ 271,HDRY,HWET,WATL,WATH,HLOW,HHI,SMAX                    00062000
            READ(5,271)RDFDAY,RDFDEL,SALTA,ESTAPT,ESTOP,AK1,AK2
            AK4=0.5/RDFDAY
            DELDAY=RDFDAY*24./RDFDEL
            RDFDAY=DELDAY
            HROOT=HLOW
            LL=1
```

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```
      SF(1)=SF(1)
      CWFLX=0.0
      DFLT=DETT
      TM=1.0-TT
      TPB=1.0-TAA
      YMAX=WATH
      RUNOF=0.0
      CUMS=0.
      MYTIME=0
      PPI=0.
      CUMP=0.0
      CUMM=0.0
      SUMA=0.0
      SCM=0.
      IPDF=0
      CTRAN=0.0
      PIT=0.0
      J=(W(1)-T(1))/DELW+1.0
      H(1)=(P(J+1)-P(J))*(W(1)-T(J))/DELW+P(J)
      C(1)=H(1)
      C(1)=DELW/(P(J+1)-P(J))
      DO 22 I=2,K
 22   PIT=W(I)*(DD(I+1)-DD(I-1))/2.+PIT
      DO 24 I=2,KK
      J=(W(I)-T(1))/DELW+1.0
      H(I)=(P(J+1)-P(J))*(W(I)-T(J))/DELW+P(J)
      C(I)=DELW/(P(J+1)-P(J))
 24   G(I)=H(I)
      WRITE(6,3)DATE
      IF(KILL.EQ.0)WRITE(6,296)
      DO 19 I=1,KK
      IF(KILL.EQ.0)WRITE(6,274)DD(I),C(I),W(I),H(I),RDFSAV(I),SE(I)
      SS(I)=SE(I)
      IF(I.EQ.1) GO TO 19
      IF(I.EQ.KK) GO TO 19
      SD(I)=SF(I)*W(I)*(DD(I+1)-DD(I-1))*0.5*SALTA
 19   V(I)=W(I)
      IF(KILL.EQ.0)WRITE(6,286)
C
C     COVER GROWTH LOOP
C
      AK3=0.5/(ESTOP-ESTART)
      DO 31 I=2,IER,2
      IR=I/2
      IF(LMM.NE.1.AND.MLX.NE.1.AND.MLX.NE.4) GO TO 31
      IF(V(I-1).GE.0.0) GO TO 31
      IF(MLX.EQ.3)V(I-1)=TET(IR)
      TET(IR)=V(I-1)
      IF(V(I)/24..LT.ESTART) GO TO 1003
      V(I-1)=TET(IR)-TET(IR)*AK1/(1.+EXP(6.-AK3*(V(I)-ESTART*24.)))
      GO TO 31
 1003 V(I-1)=TET(IR)
 31   IF(KILL.EQ.0)WRITE(6,274)V(I),V(I-1),TET(IR),SF(IR)
      WFDD=V(1)
      FOR=V(1)
      ET=TET(1)
      IF(KILL.EQ.1)GO TO 3100
```

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```
      WRITE(6,289)
      WRITE(6,274) DETT,CONQ,TAA,TIME,TT,CUMT,RRES
      WRITE (6,283)
      WRITE(6,274)HDRY,HWET,WATL,WATH,HLOW,HHI,DELW
      WRITE(6,294)
      WRITE(6,274)ALAMBA,SALTA,DIFO,DIFA,DIFB
      WRITE(6,10012)
      WRITE(6,274)RDFDAY,RDFDEL,ESTART,ESTOP,AK1,AK2
 3100 KCK=1
      HROOT=G(2)
      IF(KI.EQ.0)CALL PLOT(KK,WATH,W,DD,SMAX,SD)
      WRITE(6,295)
  34  TOP=WATH
C
C     ROOT GROWTH LOOP
      IF(IRDF.EQ.1) GO TO 10014
      IF(ABS(RDFDEL-0.).LT.1.0E-6) GO TO 10100
      IF(TIME.LT.RDFDAY) GO TO 10014
      IF(TIME.GT.DELDAY+RDFDEL) GO TO 10100
      RDFDAY=DELDAY+RDFDAY
      DROOT=DD(KK)/(1.+EXP(6.-AK4*TIME))
      J=2
      DO 10001 I=2,KK
      RDF(I)=0.
10005 IF(J.GE.KK) GO TO 10001
      ROOT(J)=DROOT*DD(J)/DD(KK)
      IF(ROOT(J).GE.DD(I)) GO TO 10002
      RDF(I)=RDFSAV(J)*(ROOT(J)-DD(I-1))/(ROOT(J)-ROOT(J-1))+RDF(I)
      IF(ROOT(J-1).GT.DD(I-1)) RDF(I)=RDFSAV(J)*(1.-((ROOT(J)-DD(I-1))/(
     1ROOT(J)-ROOT(J-1))))+RDF(I)
      J=J+1
      GO TO 10005
10002 RDF(I)=(DD(I)-DD(I-1))/(ROOT(J)-ROOT(J-1))*RDFSAV(J)+RDF(I)
      IF(ROOT(J-1).GT.DD(I-1)) RDF(I)=RDF(I)-(ROOT(J-1)-DD(I-1))/(ROOT(J
     1)-ROOT(J-1))*RDFSAV(J)
      IF(ROOT(J).GT.DD(I)) GO TO  10001
      J=J+1
10001 CONTINUE
      IF(IRTPRT.EQ.1.OR.IRTPRT.EQ.3)WRITE(6,274)(RDF(I),I=1,KK)
      GO TO 10014
10100 DO 10013 I=1,KK
10013 RDF(I)=RDFSAV(I)
      IRDF=1
10014 ROT=WATL
C
C-----COMPUTATION OF CONDUCTIVITY (B) AND WATER CAPACITY (C)
C
      HKP=H(1)
      WKP=W(1)
      IF (COR-0.0) 37,43,40
  37  V(1)=WATL
      H(1)=HDRY
      GO TO 43
  40  W(1)=WATH
      H(1)=HWET
  43  TWW=(W(1)+V(1))*0.5
      IF(TWW.GT.WATH) TWW=WATH
```

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```
      J=(TWW-T(1))/DELW+1.0
      BB=(TWW-T(J))/DELW
      DIFFA=(D(J+1)-D(J))*BB+D(J)
      HI=(P(J+1)-P(J))*BB+P(J)
      DO 76 I=1,K
      TW=(W(I+1)+Y(I+1))*0.5
      J=(TW -T(1))/DELW+1.0
      BB=(TW-T(J))/DELW
      DIFFB=(D(J+1)-D(J))*BB+D(J)
      GI=(P(J+1)-P(J))*BB+P(J)
      IF(ABS(EOR).GT.1.0E-6) GO TO 46
      B(1)=0.
      GO TO 72
   46 IF(ABS(HI-GI).LT.0.0001) GO TO 71
      B(I)=(DIFFA-DIFFB)/(HI-GI)
      IF(I.GT.1) GO TO 72
   49 EP=(B(1)*(H(1)*TT-H(2)*TT-G(2)*TM+G(1)*TM+DD(2)))/DD(2)
      IF((ABS(1.1*EOR-ER)-ABS(0.1*EOR)).LE.0.0) GO TO 52
      IF(KCK.EQ.1) GO TO 55
      IF(KCK.LT.12) GO TO 59
   52 H(1)=(EOR*DD(2)/B(1)+H(2)*TT-G(1)*TM+G(2)*TM-DD(2))/TT
      IF(H(1).LT.HDRY) H(1)=HDRY
      IF (H(1).GT.HWET) H(1)=HWET
      GO TO 72
   55 H(1)=HKP
      W(1)=WKP
      KCK=KCK+1
      GO TO 49
   59 KCK=KCK+1
      IF (ER-EOR) 61,72,64
   61 IF((W(1)-WATH).GE.0.0) GO TO 72
      BOT=W(1)
      W(1)=(W(1)+TOP)*0.5
      GO TO 67
   64 IF((W(1)-WATL).LE.0.0) GO TO 72
      TOP=W(1)
      W(1)=(W(1)+BOT)*0.5
   67 J=(W(1)-T(1))/DELW+1.0
      BB=(W(1)-T(J))/DELW
      IF(ABS(EOR-0.).LT.1.0E-06) GO TO 72
      H(1)=(P(J+1)-P(J))*BB+P(J)
   70 TWW=(W(1)+Y(1))*0.5
      J=(TWW-T(1))/DELW+1.0
      BB=(TWW-T(J))/DELW
      DIFFA=(D(J+1)-D(J))*BB+D(J)
      HI=(P(J+1)-P(J))*BB+P(J)
      GO TO 46
   71 B(I)=(D(J+1)-D(J))/(P(J+1)-P(J))
      IF(I.EQ.1) GO TO 49
   72 TWW=TW
      HI=GI
      DIFFA=DIFFB
      TW=(W(I+1)+Y(I+1))*0.5
      J=(TW -T(1))/DELW+1.0
   73 C(I+1)=DELW/(P(J+1)-P(J))
   76 CONTINUE
      KCK=1
```

```
C
C     NEW T-POT WHEN E-ACTUAL IS LESS THAN E-POT
C
      ETPL=ET
      IF(ET.GE.0.) GO TO 39
      IF(EOR.GT.0.) GO TO 365
      IF(TIME/24..LT.ESTART) GO TO 1001
      IF(ABS(WFDD-EOR).LT.1.0E-3) GO TO 1001
      ETALT=(ET-EOR)*(1.+(AK2/AK1-1.)*(EOP-WFDD)/EOR)
      IF(WFDD.LT.(ET-ETALT)) GO TO 1002
      ETPL=ETALT
      GO TO 365
 1002 ETPL=ET-WFDD
      GO TO 365
 1001 ETPL=ET-EOR
      IF(ABS(ETPL-0.).LT.1.0E-4) GO TO 39
  365 HHOLD=HROOT
      IF(IRTPRT.EQ.1.OR.IRTPRT.EQ.2)WRITE(6,271)ET,ER,EOR,ETALT,ETPL
C
C--COMPUTATION OF ROOT SINK FUNCTION
C
      SINK=0.0
C---- OP=.36*(MEQ/L)/10*1000CM/ATM   MEQ/L=10MILLIMHOS/CM
      DO 249 I=2,K
  249 E(I)=S(I)-36.*SC(I)-DD(I)*RRES
      LCNT=0
  412 DSAVE=DSINK
      DSINK=0.
      SINK=ETPL
      DO 420 I=2,K
      IF(HROOT-E(I).GT.0.) GO TO 420
      SINK=SINK+B(I)*RDF(I)*E(I)
      DSINK=DSINK+B(I)*RDF(I)
  420 CONTINUE
      IF(DSINK.NE.0.) GO TO 410
      IF(HROOT.EQ.HLOW) GO TO 402
      HROOT=HLOW
      GO TO 412
  410 IF(DSINK.EQ.DSAVE) GO TO 402
      HROOT=SINK/DSINK
      IF(HROOT.LT.HLOW) HROOT=HLOW
      LCNT=LCNT+1
      IF(LCNT.LE.20) GO TO 412
      WRITE(6,422)
  422 FORMAT('  LCNT.EQ.20')
  402 SINK=0.
      DO 406 I=2,K
      IF(HROOT-E(I).GT.0.)GO TO 407
      A(I)=B(I)*2.*RDF(I)*(HROOT-E(I))/(DD(I+1)-DD(I-1))
      SINK=SINK+RDF(I)*B(I)*(HROOT-E(I))
      GO TO 406
  407 A(I)=0.
  406 CONTINUE
      GO TO 106
   39 DO 251 I=2,K
      SINK=0.
  251 A(I)=0.
```

```
      C
      C     WATER FLOW TRIDIAGONAL MATRIX SOLUTION
      C
        106 DO 118 I=2,K
            POT=(DD(I+1)-DD(I-1))/(2.0*DELT)                                  B 160
            DLXA=(DD(I)-DD(I-1))                                              B 161
            DLXB=(DD(I+1)-DD(I))                                              B 162
            BB=C(I)*POT/TT+B(I)/DLXB+B(I-1)/DLXA                              B 1621
            DA=(C(I)*POT*G(I)+(B(I)/DLXB)*(TM*(G(I+1)-G(I))-DLXB)+(B(I-1)/DLXA B 1622
           1)*(TM*(G(I-1)-G(I))+DLXA)+A(I)*(DD(I+1)-DD(I-1))*0.5)/TT
            IF(I.GT.2.0) GO TO 115
            IF(H(1).GE.HWET.OR.H(1).LE.HDRY) GO TO 109
            DA=DA-((B(I-1)/DLXA)*(TM*(G(I-1)-G(I))+DLXA))/TT*EOR/TT
            BB=BB-B(I-1)/DLXA
            GO TO 112
        109 DA=DA+H(I-1)*B(I-1)/DLXA
        112 F(I)=DA/BB
            E(I)=(B(I)/DLXB)/BB                                               B 1661
            GO TO 118
        115 IF(I.GE.K) GO TO 121
            E(I)=(B(I)/DLXB)/(BB-(B(I-1)/DLXA)*F(I-1))
            F(I)=(DA+(B(I-1)/DLXA)*F(I-1))/(BB-(B(I-1)/DLXA)*E(I-1))          B 170
        118 CONTINUE
        121 BB=BB-TAA*B(I)/DLXB
            DA=DA+TAA*(B(I)/DLXB)*((G(I)-G(I+1))*TM+DLXB)/TT+TBB*B(I)/DLXB*H(  B 173
           1KK)                                                               B 174
            H(I)=(DA+(B(I-1)/DLXA)*F(I-1))/(BB-(B(I-1)/DLXA)*E(I-1))          B 1741
        124 I=I-1
            H(I)=E(I)*H(I+1)+F(I)                                             A 176
            IF(I.GT.2) GO TO 124
            IF(TAA.LT.1.0) GO TO 127
            H(KK)=H(K)+DD(KK)-DD(K)
            G(KK)=G(K)+DD(KK)-DD(K)
            B(K)=0.0
        127 DO 131 I=2,K
        130 IF(H(I)-DD(I)-HWET.LE.0.)GO TO 131
            H(I)=HWET+DD(I)
        131 CONTINUE
      C
      C----COMPUTATION OF WATER CONTENTS AS A FUNCTION OF PRESSURES JUST COMP  A 199
      C
            IF(H(1).GE.HWET.OR.H(1).LE.HDRY) GO TO 136
            WFDD=EOR
            IF(ABS(EOR).GT.1.0E-6) GO TO 134
            H(1)=H(2)
            GO TO 139
        136 WFDD=B(1)*((H(1)-H(2))*TT+(G(1)-G(2))*TM+DD(2))/DD(2)
            IF(IRTPRT.NE.6)GO TO 139
            WRITE(6,390)
        390 FORMAT(' AFTER   136')
            WRITE(6,391)TIME,WFDD,H(1),H(2),G(1),G(2),DELT,EOR,ER,KCK
        391 FORMAT(' '9E10.4,I3)
            GO TO 139
        134 H(1)=(EOR*DD(2)/B(1)+H(2)*TT-G(1)*TM+G(2)*TM*DD(2))/TT
            IF(IRTPRT.NE.6)GO TO 392
            WRITE(6,393)
        393 FORMAT(' AFTER   134')
      WRITE(6,391)TIME,WFDD,H(1),H(2),G(1),G(2),DELT,EOR,ER,KCK
  382 IF(H(1).LT.HDRY) H(1)=HDRY
      IF (H(1).GT.HWET) H(1)=HWET
  139 I=1
  142 IF(ABS(H(I)-G(I)).LT.0.0001) GO TO 160
      NHI=ND
      NLO=1                                                             A 207
      J=25                                                              A 208
  145 IF (H(I)-P(J)) 148,157,151
  149 NHI=J
      GO TO 154
  151 NLO=J
  154 JT=J
      J=(NHI-NLO)/2+NLO                                                 A 214
      IF(ABS(J-JT).GT.0.00) GOTO 145
      IF(H(I).GE.P(J)) GO TO 157
      J=J-1
  157 WAT=(H(I)-P(J))*DELW/(P(J+1)-P(J))+T(J)
      W(I)=WAT
      GO TO 163
  160 W(I)=Y(I)
  163 DO 166 I=2,KK
      W(I)=C(I)*(H(I)-C(I))+Y(I)
      IF(W(I).GT.WATH) W(I)=WATH
      IF(W(I).LT.WATL) W(I)=WATL
  166 CONTINUE
  169 SUM3=0.0
      SUM2=0.0                                                          A 326
      SUM1=0.0
      DO 172 I=2,K
      SUM1=W(I)+SUM1                                                    A 328
      SUM2=Y(I)+SUM2                                                    A 329
      IF(ABS(SUM1-SUM2).LE.ABS(SUM3)) GO TO 172
      SUM3=SUM1-SUM2
  172 CONTINUE
      IF(ABS(SUM3).LE.ABS(CONQ)) GO TO 175
      IF(DELT.LE.DETT*0.1) GO TO  175
      DELT=0.5*DELT
      GO TO 106
  175 SUM1=0.0
      SUM2=0.0
      DO 178 I=2,K
      SUM1=W(I)*(DD(I+1)-DD(I-1))/2.+SUM1
  178 SUM2=Y(I)*(DD(I+1)-DD(I-1))/2.+SUM2
      CWF=SUM1-PIT
      WFRDD=(SUM1-SUM2)/DELT
      WFUU=B(NB)*(((H(NB)-H(NB+1))*TT+(G(NB)-G(NB+1))*TM*DD(NB+1)-DD(NB))
     1/(DD(NB+1)-DD(NB))
      CUMS=WFDD*DELT+CUMS                                               A 341
      CUMB=WFUU*DELT+CUMB
      SUMA=SUMA+SINK*DELT
      CTRAN=CTRAN+ETPL*DELT
      CWFLX=(SUM1-SUM2)                                                A343A
      KB=K-1
      IF(EOR.GE.0.)RPI=RPI+EOR*DELT
C
C----SALT LOOP                                                         00362000
C
      WFRU=B(1)+((H(1)-H(2))*TT+(G(1)-G(2))*TM*DD(2))/DD(2)
      IF(WFRU.LT.0.)WFRU=0.
      ALFA=0.0                                                          00377000
      WATU=(Y(1)*TM+W(1)*TT+Y(2)*TM+W(2)*TT)/2.
      DO 214 I=2,K
      DLXA=(DD(I)-DD(I-1))
      DLXB=(DD(I+1)-DD(I))
      DLXC=(DD(I+1)-DD(I-1))*0.5
      WFRD=B(I)+((H(I)-H(I+1))*TT+(G(I)-G(I+1))*TM*DLXB)/DLXB
      WATD=(Y(I)*TM+W(I)*TT+Y(I+1)*TM+W(I+1)*TT)/2.0
      BETA=DIFO+DIFA*EXP(DIFB*WATD)+ALAMDA*ABS(WFRD/WATD)
      TW=DELT*(W(I)-Y(I))*(WFRD+WFRU)/(8.*(W(I)+Y(I)))
      AX=TW*WFRU/(DLXA*WATU)+ALFA/DLXA+WFRU*0.5
      IF(I.EQ.2)AX=WFRU
      CX=TW*WFRD/(DLXB*WATD)+BETA/DLXB-WFRD*0.5
      BB=W(I)*DLXC/(TT*DELT)-AX+2.*ALFA/DLXA+CX+WFRD
      DA=(Y(I)*SS(I)*DLXC/DELT+TM*(AX*(SS(I-1)-SS(I))+WFRU*SS(I)-CX*(SS
     1I)-SS(I+1))-WFRD*SS(I)))/TT
      IF(I.GT.2)GO TO 188
      DA=DA+AX*SS(I-1)
      BB=BB+AX-2.*ALFA/DLXA
      F(I)=DA/BB
      E(I)=CX/BB
      GO TO 213
  188 IF(I.GE.K) GO TO 189
      E(I)=CX/(BB-AX*E(I-1))
      F(I)=(DA+AX*F(I-1))/(BB-AX*E(I-1))
  213 ALFA=BETA
      WATU=WATD
      IF(KP.EQ.3)WRITE(6,274)WFRU,WFRD,WATD,W(I),DELT,BETA,SS(I),TW,AX,
     1BB,CX
  214 WFRU=WFRD
  189 DA=DA+CX*SS(I+1)
      SE(I)=(DA+AX*F(I-1))/(BB-AX*E(I-1))
  190 I=I-1
      SE(I)=E(I)*SE(I+1)+F(I)
      IF(I.GT.2)GO TO 190
      SE(KK)=SS(KK)
      DO 191 I=2,K
      IF(SE(I).GE.SE(I-1).OR.SE(I).GE.SE(I+1)) GO TO 191
      IF(I.EQ.2) GO TO 192
      IF(I.EQ.K) GO TO 193
      IF(KS.EQ.1) GO TO 191
      KG=KG+1
      IF (SE(I-1).LE.SE(I+1)) GO TO 192
  193 TW=(SE(I+1)-SE(I))*W(I)*(DD(I+1)-DD(I-1))*0.5
      SE(I-1)=SE(I-1)-TW/(W(I-1)*(DD(I)-DD(I-2))*0.5)
      SE(I)=SE(I+1)
      GO TO 191
  192 TW=(SE(I-1)-SE(I))*W(I)*(DD(I+1)-DD(I-1))*0.5
      SE(I+1)=SE(I+1)-TW/(W(I+1)*(DD(I+2)-DD(I))*0.5)
      SE(I)=SE(I-1)
  191 CONTINUE
      SD(1)=SE(1)*W(1)*0.5*DD(2)
      SALT=0.0                                                          00403000
      SCM=WFRD*SS(K)*DELT*SALTA+SCM
      IF(WFRD.LT.0.)SCM=WFRD*(SS(KK)-SS(K))*DELT*SALTA+SCM
      DO 217 I=2,K
      SD(I)=SE(I)*W(I)*(DD(I+1)-DD(I-1))*0.5*SALTA
  217 SALT=SD(I)+SALT
      IF(EOR.LE.0) GO TO 220
      RUNOF=(EOR-WFDD)*DELT+RUNOF                                     A 345
  220 TIME=TIME+DELT
      IF(KI.NE.0) GO TO 500
      IF(KP.EQ.2) GO TO 500
      IF(LL.LT.MM) GO TO 223
      CALL PLOT (KK,WATH,W,DD,SMAX,SD)
      WRITE (6,274) (H(I),I=1,KK)
      WRITE(6,274)(SE(I),I=1,KK)
      WRITE(6,274)(A(I),I=2,K)
      WRITE (6,295)
      LL=0                                                            A 352
  223 WRITE (6,555)TIME,CWF,SCM,WFDD,RUNOF,CUMS,CUMB,SUMA,CTPAN,WFRDD,S 00411000
     1ALT,HROOT
  500 IF(ABS(SUM3-0.).GT..0001) GO TO 229                               00413000
  226 DELT=3.*DELT
      GO TO 241
  229 TW=ABS(CON2*DELT/SUM3)
  232 IF(TW.GE.0.1*DETT) GO TO 235
      TW=0.1*DETT
      GO TO 238
  235 IF(TW.LE.1000.0*DETT) GO TO 238
      TW=1000.0*DETT
  238 IF(TW.GT.2.0*DELT) GO TO 226
      DELT=TW
C
C----TEST TO SEE IF EVAP OR RAIN INTENSITY (EOR) HAS CHANGED           A 365
C
  241 IF(IDELT.EQ.1) DELT=DELT1
      IDELT=0
      IF(DELT.LT.DETT)DELT=DETT
      IF(DELT.GT.6.) DELT=6.
      IF(ABS(TIME-V(KC+1)).GT.0.0001)GO TO 247
      IF(KI.NE.0) GO TO 501                                             00425100
      CALL PLOT (KK,WATH,W,DD,SMAX,SD)
      WRITE (6,274) (H(I),I=1,KK)
      WRITE(6,274)(SE(I),I=1,KK)
      IF(KS.EQ.2)WRITE(6,268)K6
      K6=0
      WRITE(6,295)
  501 IF(KA.EQ.0)WRITE(6,555)TIME,CWF,SCM,WFDD,RUNOF,CUMS,CUMB,SUMA,CTPA00432000
     1N,WFRDD,SALT,HROOT                                                00433000
      EOR=V(KC+2)
      IR=(KC+2)/2
      SF(1)=SF(IR+1)
      ET=TET(IR+1)
      KC=KC+2
      NTIME=0
      DELT=DETT
      GO TO 250
  247 IF((TIME+DELT).LE.V(KC+1)) GO TO 250
      DELT=V(KC+1)-TIME
  250 LL=LL+1
```

```
C
C     CALCULATION OF HOURLY ET DEMAND FROM LYSIMETER DATA
C
      IF(V(KC).GT.0.) GO TO 2251
      LTIME=TIME/24
      TIMEL=LTIME
      TIMEA=TIME/24.-TIMEL
      LTIME=(TIME+DELT)/24
      TIMEL=LTIME
      TIMED=(TIME+DELT)/24.-TIMEL
      IF(TIMED.LT.TIMEA) GO TO 254
      IF(0.5-TIMEA.LT.0.0001)GO TO 254
      IF(TIMED.LE.0.5)GO TO 2252
      TIMED=0.5
      DELT1=DELT
      IDELT=1
      DELT=(0.5-TIMEA)*24.
 2252 IF(MTIME.EQ.1)GO TO 257
      MTIME=1
      TIMEC=V(KC+1)-TIME
      IF(TIMEC+24.*TIMEA.GT.24.)TIMEC=24.*(1.-TIMEA)
      EORH2O=V(KC)*TIMEC
      IR=(KC+1)/2
      ETH2O=TET(IR)*TIMEC
      TIMEL=TIMEC
      IF(TIMEC.GE.12.)TIMEL=12.
      DENOM=COS(TIMEA*6.2832)-COS(TIMEL*6.2832/24.)
  257 ETNEW=(COS(TIMEA*6.2832)-COS(TIMED*6.2832))/DENOM
      EOR=ETNEW*EORH2O/DELT
      ET=ETNEW*ETH2O/DELT
      GO TO 2251
  254 IF(TIMED.GE.0.5)GO TO 2253
      DELT1=DELT
      IDELT=1
      DELT=(1.-TIMEA)*24.
 2253 ET=0.
      EOR=0.
      MTIME=0
 2251 IF(IRTPRT.EQ.1.OR.IRTPRT.EQ.4)WRITE(6,274) TIME,EOR,ET,TIMEA,TIMEC
     1,TIMED,DENOM,ETNEW
      IF(DELT.LT.DETT) DELT=DETT
      IF(TIME-CUMT.LT.-0.0001) GO TO 253
      IF(MT.EQ.0) GO TO 41
      CALL PLOT (KK,WATH,W,DD,SMAX,SD)                                  00470000
      WRITE (6,274) (W(I),I=1,KK)                                       00471000
      WRITE(6,274)(SE(I),I=1,KK)                                        00471010
   41 IF(IRTPRT.NE.5) GO TO 42
      W4=0.
      S4=0.
      DO 44 I=2,K
      S4=S4+SE(I)*(DD(I+1)-DD(I-1))*0.5
   44 W4=W4+ W(I)*(DD(I+1)-DD(I-1))*0.5
      DD4=DD(KK)-0.5*(DD(KK)-DD(K)+DD(2)-DD(1))
      W4=W4/DD4
      S4=S4/DD4
      T4=SUMA/CTRAN
      ET=CWF-CUMB+CUMS
      WRITE(6,45)
      WRITE(6,555)TIME,RPI,ET,SUMA,T4,CUMB,SCM,SE(KK),S4,W4
 42   IF(ML-LMM)267,267,15
 15   IF(MLM.EQ.1) GO TO 14
      GO TO 13
 253  Y(1)=(W(1)+Y(1))*0.5
      J=(Y(1)-T(1))/DELW+1.0
      BB=(Y(1)-T(J))/DELW                                                A 389
      IF(ABS(EOP-0.0).LT.0.0001) GO TO 256
      C(1)=(P(J+1)-P(J))*BB+P(J)
 256  DO 265 I=2,KK
      J=(W(I)-T(1))/DELW+1.0
      BB=(W(I)-T(J))/DELW
      G(I)=(P(J+1)-P(J))*BB+P(J)
      TW=(W(I)-Y(I))+W(I)                                                A 395
      IF(TW.GT.WATH) GO TO 259
      IF(TW.GE.WATL) GO TO 262
      TW=WATL
      GO TO 262
 259  TW=WATH
 262  Y(I)=W(I)
      W(I)=TW                                                            A 402
      SS(I)=SE(I)
 265  CONTINUE
      SS(1)=SE(1)
      GO TO 34
 267  CONTINUE
 263  STOP                                                              00471020
 3    FORMAT('1',70A1)
 45   FORMAT('0    TIME    IRR + RAIN    ET       TRAN ACT     YIELD    D
     1RAINAGE     SCM     INIT SALT  FINAL SALT  AVE WATER')
 268  FORMAT (20I3)
 271  FORMAT (7E10.4)
 286  FORMAT('0  TIME END   SOIL FLUX  ET FLUX    SALT CONC.')          00480010
 274  FORMAT (11E12.5)                                                  00471000
 555  FORMAT(12E11.4)                                                   00471100
 295  FORMAT      ('0 TIME         CWF         SCM         WFDD        RUN
     1    CUMS         CUMB      TRANACT       TRANPOT    WFROD      SALT
     2    HROOT')
 280  FORMAT('0   WATER      POTENTIAL CONDUCTIVITY DIFFUSIVITY
     1       WATER     POTENTIAL CONDUCTIVITY DIFFUSIVITY')
 275  FORMAT(4E12.5,12X,4E12.5)
 296  FORMAT('0   DEPTH         C(I)       W-DEPTH     H-DEPTH   ROF-DEPTH
     1    SE-DEPTH')
10012 FORMAT('    ROFDAY    ROFDEL     ESTART     ESTOP        AK1
     1 AK2')
 277  FORMAT('OK MM IER NB ND KT KP KA IRTPRT')
 289  FORMAT(80H   DETT          CONO          TAA          TIME        TT
     1          CUMT         RRES)
 283  FORMAT('   HDRY          HWET         WATL          WATH         HLOW
     1     HHI          DELW')
 284  FORMAT('   ALAMBA       SALTA        DIFO         DIFA         DIFB')
      END
```

<••>

APPENDIX B

FIELD DATA

Table B-1. Climatic data for 1972.

Date	Rs (Ly/day)	Wind (km/day)	Td (^{o}C)	Tw (^{o}C)	ET east (cm)	ET west (cm)
6-24-72	569	185	16	12	-.49	0
6-25	690	140	14	11	.32	-.65
6-25	690	140	14	11	.33	-.65
6-27	678	190	15	14	.43	2.70
6-28	724	78	19	13	2.04	.36
6-29	710	76	18	11	-.11	-1.46
6-30	712	95	16	13	.16	.27
7-1	667	132	16	4	.49	.54
7-2	667	132	16	11	.49	.54
7-3	667	132	16	11	.49	.54
7-4	733	110	16	11	.11	.70
7-5	745	95	15	11	.43	.54
7-6	547	105	17	13	.16	.54
7-7	627	138	16	13	.52	.81
7-8	636	105	16	13	.52	.81
7-9	598	135	18	15	.52	.81
7-10	598	135	18	15	.52	.81
7-11	675	113	17	14	-.67	-.34
7-12	620	109	19	14	.97	.92
7-13	619	78	21	16	1.03	.76
7-14	651	109	18	16	1.40	1.00
7-15	701	93	18	14	.72	1.06
7-16	701	93	18	14	.72	1.06
7-17	701	93	18	14	.72	1.06
7-18	613	97	18	14	.54	.92
7-19	592	161	18	14	.92	1.24
7-20	521	174	20	15	1.08	1.13
7-21	672	177	19	14	.92	1.08
7-21	565	117	18	13	1.14	.43
7-23	561	97	17	13	.63	.74
7-24	561	97	17	13	.63	.74
7-25	561	97	17	13	.63	.74
7-26	576	82	17	15	.97	.97
7-27	426	88	17	15	.53	.48
7-28	582	90	16	13	.21	.97
7-29	634	103	18	15	1.24	1.35
7-30	634	103	18	15	1.24	1.35
7-31	634	103	18	15	1.24	1.35
8-1	580	100	20	15	1.73	1.40

Table B-1. Climatic data for 1972 (Continued).

Date	Rs (Ly/day)	Wind (km/day)	Td (°C)	Tw (°C)	ET east (cm)	ET west (cm)
8-2	600	132	18	14	.61	.60
8-3	0	111	16	14	.61	.60
8-4	577	84	14	12	1.19	1.03
8-5	527	95	15	12	.40	.14
8-6	527	95	15	12	.40	.14
8-7	527	95	15	12	.40	.14
8-8	708	85	17	13	.08	.14
8-9	547	110	17	13	.81	.59
8-10	653	85	14	12	.54	.70
8-11	579	98	16	13	.76	1.24
8-12	599	92	19	16	.61	.75
8-13	599	92	19	16	.61	.75
8-14	599	92	19	16	.61	.75
8-15	514	93	16	15	.64	1.24
8-16	603	104	18	15	.59	.27
8-17	0	84	18	14	.59	.65
8-18	615	82	17	14	.55	.60
8-19	461	90	14	13	.25	.57
8-20	461	90	14	13	.25	.57
8-21	461	90	14	13	.25	.57
8-22	590	76	13	12	.76	.97
8-23	418	72	16	13	.32	.32
8-24	619	234	14	11	1.19	1.19
8-25	619	98	11	9	.32	.38
8-26	562	106	13	11	.74	.88
8-27	562	106	13	11	.74	.88
8-28	562	106	13	11	.74	.88
8-29	576	77	14	12	1.54	1.16
8-30	562	117	13	11	.65	1.08
8-31	504	101	14	11	.49	.54
9-1	446	77	12	10	.42	.40
9-2	418	92	13	11	.42	.40
9-3	418	92	13	11	.42	.40
9-4	418	92	13	11	-.07	.75
9-5	518	92	16	14	.23	.34
9-6	228	119	15	13	1.28	1.31
9-7	562	130	11	9	1.28	.92
9-8	561	82	11	9	.39	.58
9-9	461	98	15	12	.39	.58

Table B-1. Climatic data for 1972 (Continued).

Date	Rs (Ly/Day)	Wind (km/day)	Td (^{o}C)	Tw (^{o}C)	ET east (cm)	ET west (cm)
9-10	461	98	15	12	.39	.58
9-11	461	98	15	12	.92	.70
9-12	490	167	14	11	.65	.49
9-13	576	105	11	7	.38	.59
9-14	547	80	9	5	.49	.76
9-15	547	84	12	8	.58	.85
9-16	532	109	13	10	.58	.85
9-17	532	109	13	10	.58	.85
9-18	532	103	13	10	.47	.25
9-19	461	116	14	11	.59	.59
9-20	216	105	13	11	.16	.47
9-21	518	82	10	8	.16	.47
9-22	504	71	10	8	.16	.47
9-23	418	84	9	5	.16	.47
9-24	418	84	9	5	.16	.47
9-25	418	84	9	5	.16	.47
9-26	418	84	9	5	.49	.22

Table B-2. Lysimeter evapotranspiration (ET) and temperature (T) data for 1973.

Date	ET east (cm)	ET west (cm)	T wet (^{o}C)	T dry (^{o}C)	T max (^{o}C)	T min (^{o}C)
6-16-73	-	-	-	-	23	1
6-17	-	-	-	-	26	5
6-18	-		-	-	21	1
6-19	-	-	-	-	21	0
6-20	.74	.85	-	-	32	4
6-21	-	-	-	-	30	7
6-22	.48	.26	11	16	29	7
6-23	.64	.95	-	-	34	7
6-24	.80	.90	-	-	33	12
6-25	.79	.90	13	14	36	13
6-26	.85	1.48	16	22	35	12

Table B-2. Lysimeter evapotranspiration (ET) and temperature (T) data for 1973 (Continued).

Date	ET east (cm)	ET west (cm)	T_{wet} (°C)	T_{dry} (°C)	T_{max} (°C)	T_{min} (°C)
6-27	.74	1.01	16	17	35	14
6-28	.80	.85	14	18	33	15
6-29	1.22	.42	15	18	36	10
6-30	.29	.93	-	-	36	13
7-1	.29	.93	12	32	34	14
7-2	1.64	1.01	13	16	35	10
7-3	.64	.74	16	17	36	14
7-4	.53	.58	15	18	36	12
7-5	.53	.62	18	25	37	12
7-6	0	.64	12	14	37	11
7-7	.65	.74	-	-	37	13
7-8	.65	.74	-	-	33	11
7-9	.65	.74	14	17	35	12
7-10	.69	1.06	13	16	36	12
7-11	.48	.90	13	17	35	13
7-12	.64	.85	17	19	37	16
7-13	.54	.64	17	18	32	16
7-14	.54	.37	15	17	26	13
7-15	.02	.23	-	-	27	13
7-16	.02	.23	12	12	29	10
7-17	.05	.90	13	15	33	9
7-18	.64	.53	11	12	31	11
7-19	.85	.38	17	18	29	14
7-20	.34	.34	16	16	26	10
7-21	.58	.66	-	-	29	9
7-22	.58	.66	-	-	28	10
7-23	.58	.66	-	-	29	4
7-24	.58	.66	15	17	23	10
7-25	.69	.85	14	17	28	12
7-26	.42	.69	12	14	32	10
7-27	.58	.90	16	18	34	10
7-28	.74	.85	15	17	33	11
7-29	.64	.56	-	-	34	11
7-30	.64	.56	16	19	31	11
7-31	.05	.26	12	13	33	12
8-1	.48	.58	15	21	35	11
8-2	1.11	.11	13	17	30	12
8-3	.37	.11	12	15	33	10
8-4	.04	.39	-	-	33	12
8-5	.04	.39	-	-	32	12
8-6	.04	.39	14	16	28	11
8-7	.64	.58	16	18	34	9
8-8	.65	.58	-	-	34	9
8-9	.65	0	12	14	33	7
8-10	0	.64	13	14	36	10

Table B-2. Lysimeter evapotranspiration (ET) and temperature (T) data for 1973 (Continued).

Date	ET east (cm)	ET west (cm)	T_{wet} (°C)	T_{dry} (°C)	T_{max} (°C)	T_{min} (°C)
8-11	.58	.85	-	-	36	10
8-12	.58	.85	-	-	34	10
8-13	.58	.85	12	17	34	10
8-14	.58	.69	11	14	37	12
8-15	.80	1.06	13	17	34	9
8-16	1.21	1.32	12	15	36	10
8-17	.66	.61	16	17	33	12
8-18	.79	.74	23	19	32	12
8-19	.42	.58	13	14	34	12
8-20	1.23	-.05	19	22	31	13
8-21	.62	.72	16	17	32	13
8-22	.47	.68	17	29	28	12
8-23	.37	.58	16	16	34	14
8-24	.58	1.06	18	22	32	13
8-25	.97	1.08	-	-	32	7
8-26	.97	1.08	-	-	32	9
8-27	.97	1.08	16	17	-	10
8-28	.74	.95	11	13	-	6
8-29	.48	.79	12	13	-	4
8-30	.64	.95	13	16	-	7
8-31	.16	.08	-	-	29	7
9-1	.16	.08	-	-	19	7
9-2	.16	.08	-	-	16	2
9-3	.16	.08	8	9	21	3
9-4	.64	.69	11	15	24	4
9-5	.64	.48	9	11	28	4
9-6	.62	-.28	9	11	29	8
9-7	.32	.80	9	11	30	7
9-8	.42	.57	-	-	23	10
9-9	.42	.57	-	-	25	5
9-10	.42	.57	-	-	24	11
9-11	.42	.57	14	16	18	11
9-12	.47	.42	12	13	21	4
9-13	.42	.48	11	11	27	4
9-14	.42	.26	11	36	29	10
9-15	.39	1.13	-	-	28	7
9-16	.39	1.13	-	-	28	7
9-17	.39	1.13	7	10	26	2
9-18	.80	1.06	-	-	28	4

Table B-3. Dates of irrigation, amount applied, and EC of irrigation water on Hullinger Farm in 1972.

Date	Amount (cm)	EC (mmho/c)	Date	Amount (cm)	EC (mmho/c)	Date	Amount (cm)	EC (mmho/c)
Block 1 - Corn			**Block 3 - Alfalfa**			**Block 5 - Alfalfa**		
5-23	5.4	---	5-23	5.1	---	5-24	5.1	---
6-28	5.7	1.0	6-23	5.1	0.9	6-22	5.1	---
7- 6	10.2	1.0	6-25	5.1	1.1	6-27	14.6	1.1
7-12	3.7	1.0	6-26	5.1	1.1	7-10	5.1	1.0
7-21	10.5	1.0	7-10	7.0	1.0	7-21	8.6	1.0
7-26	4.4	1.6	7-14	2.4	1.0	8- 7	4.4	1.6
8- 3	7.9	1.6	7-18	3.5	0.9	8-17	7.6	0.9
8-15	5.1	1.2	8- 4	15.2	1.4	8-28	6.4	0.8
8-22	3.5	1.3	8- 7	1.6	1.6	9- 6	7.0	1.0
8-29	5.7	0.9	8-11	3.3	0.9			
9- 4	3.2	0.9	8-15	3.2	1.2	**Block 6 - Alfalfa**		
9-13	3.5	1.3	8-18	1.4	1.0			
			8-21	2.2	1.3	5-25	5.7	---
Block 1 - Alfalfa			8-24	2.2	0.9	6-24	10.2	0.9
			8-28	2.9	0.8	6-28	1.9	1.1
5-23	5.4	---	8-31	1.3	0.9	7-11	5.6	1.0
7- 6	10.2	1.0	9- 4	3.2	0.9	7-19	7.5	0.8
7-19	3.7	0.8	9- 7	0.6	1.3	8-10	9.1	1.0
7-26	4.4	1.6	9-12	2.9	1.1	8-11	5.6	0.9
8- 3	7.9	1.6				8-16	4.1	1.1
8-11	15.2	0.9	**Block 4 - Alfalfa**			8-24	5.7	0.8
8-15	5.1	1.2				8-31	4.8	1.0
8-22	3.5	1.3	5-24	5.1	---	9- 5	1.9	1.3
			6-23	5.1	0.8	9-12	3.2	1.2
Block 2 - Alfalfa			6-25	5.1	1.2			
			6-26	5.1	1.1	**Block 7 - Corn**		
5-26	1.0	---	7-11	5.9	1.0			
6-23	5.1	0.9	7-18	5.9	0.9	5-25	2.9	---
6-24	5.1	0.9	8- 8	9.2	1.6	6-22	2.5	---
6-26	5.1	1.1	8-10	5.1	1.2	6-28	6.0	1.2
7-13	10.2	0.8	8-15	4.8	1.2	7- 7	8.6	1.0
7-19	1.8	0.8	8-24	5.1	0.8	7-11	3.8	1.0
8- 7	14.3	1.6	8-30	5.1	0.9	7-19	8.9	0.8
8-11	8.3	0.8	9- 5	2.2	1.2	7-25	7.8	1.4
8-23	14.3	1.0	9-12	3.2	1.2	8- 2	7.0	1.5
8-28	7.9	0.9				8- 3	2.2	1.6
9- 5	16.2	1.2				8- 9	5.4	1.3
						8-16	7.3	1.1
						8-22	4.8	1.2
						8-29	7.0	0.9
						9- 4	3.8	0.9
						9-12	5.1	1.2

Table B-3. Dates of irrigation, amount applied, and EC of irrigation water on Hullinger Farm in 1972 (Continued).

Date	Amount (cm)	EC (mmho/c)	Date	Amount (cm)	EC (mmho/c)
Block 8 - Corn			Block 9 - Corn		
5-25	6.4	---	5-23	5.4	---
6-22	2.9	---	6-24	3.2	0.9
6-28	3.8	1.0	6-28	5.7	1.0
7- 5	10.2	0.9	7- 5	10.2	1.0
7-12	4.8	1.0	7-12	4.1	1.0
7-20	7.1/9.0[a]	0.9/0.9[a]	7-20	7.9	1.0
7-25	5.4/7.5[a]	1.4/1.5[a]	7-26	4.9	1.6
8- 3	7.0/9.5[a]	1.5/1.5[a]	8- 3	7.6	1.5
8- 9	4.1/5.5[a]	1.3/1.3[a]	8- 9	4.1	1.3
8-17	5.1/7.0[a]	0.9/0.9[a]	8-17	5.9	0.9
8-22	3.5/4.9[a]	1.1/1.1[a]	8-23	3.0	1.2
8-30	5.4/7.2[a]	1.0/0.9[a]	8-29	4.8	1.0
9- 5	2.5/3.1[a]	1.0/1.1[a]	9- 5	3.5	1.0
9-13	4.1/5.4[a]	---	9-13	3.8	---

[a] First figure is for plots 5AM and 5AS. Second figure is for plot 5AN.

Table B-4. Dates of irrigation, amount applied and EC of irrigation water on Hullinger Farm in 1973.

Date	Amount (cm)	EC (mmho/c)	Date	Amount (cm)	EC (mmho/c)	Date	Amount (cm)	EC (mmho/c)
Block 1 - Corn			Block 4 - Alfalfa[a]			Block 8 - Corn		
6-21	1.3	---	5-25	7.6	---	7- 2	5.1	0.6
6-25	1.3	---	6-17	7.6	---	7-13	6.7	0.8
7- 1	5.1	0.7	7- 4	7.6	0.6	7-20	3.8	0.9
7-10	6.7	0.8	7-11	7.3	0.7	7-31	5.1	0.9
7-20	5.7	1.0	8- 7	8.9	1.2	8- 9	5.1	1.2
8- 1	5.1	1.2	8-19	7.2	0.9	8-21	5.3	0.9
8- 9	5.1	1.2	9- 4	7.9	1.5			
8-21	4.9	1.0				Block 9 - Corn East		
			Block 5 - Alfalfa[a]					
Block 1 - Alfalfa						7- 3	5.1	0.7
			5-26	7.6	---	7-14	6.7	0.8
5-28	5.1	---	6-17	7.6	1.5	7-20	5.7	1.0
6-14	7.6	---	7- 5	7.6	0.7	8- 1	5.1	1.2
7- 1	5.1	---	7-12	6.7	0.7	8- 9	5.1	1.2
7-10	6.7	0.7	8- 8	8.9	1.2	8-21	4.9	1.0
8- 9	5.1	1.2	8-19	7.1	0.9			
8-21	4.9	1.0	9- 5	7.7	1.4	Block 9 - Corn West		
Block 2 - Alfalfa			Block 6 - Alfalfa			6-21	1.3	---
						6-25	1.3	---
5-24	7.6	---	5-26	7.6	---	7- 3	5.1	0.7
6-15	12.1	---	6-15	7.6	---	7-14	6.7	0.8
7- 1	6.4	0.8	7- 5	7.6	0.7	7-20	5.7	1.0
7-10	6.7	0.7	7-12	6.7	0.7	8- 1	5.1	1.2
8- 6	8.9	1.3	8- 8	8.9	1.2	8- 9	5.1	1.2
8-18	7.0	1.0	8-20	7.0	0.9	8-21	4.9	1.0
9- 3	7.7	1.5	9- 5	7.6	1.5			
Block 3 - Alfalfa[a]			Block 7 - Corn					
5-25	7.6	---	7- 2	5.1	0.7			
6-16	7.6	---	7-13	6.7	0.8			
7- 2	2.2	0.6	7-20	3.8	0.9			
7- 3	5.4	0.6	7-31	5.1	0.9			
7-11	6.7	0.7	8- 9	5.1	1.2			
8- 6	8.9	1.3	8-20	5.1	0.9			
8-18	7.0	1.0						
9- 4	7.4	1.3						

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[a] As part of an independent study of drain performance (Sabti; 1974), plots over drains 1N, 2N, and 3N received two additional irrigations of 15.2 cm each on 6-19 and 6-25. EC for these two irrigations not available.

Table B-5. Discharge of tile drains on Hullinger farm in 1972. A blank in the data indicates no flow.

(m³/hr)

Date	Drain[b]												
	3N	4N	4M	4S	5N	5M	5S	5AN	5AM	5AS	6N	6M	6S
6-28	1.02	1.02	0.06					0.04	*		0.03		
6-29	0.31	0.61	0.10		1.02	0.20		0.07	0.02		0.04		
6-30		0.20	0.03		1.02	0.20		0.03	0.01		0.01		
7-3					0.10	0.01							
7-5					0.06								
7-7					1.02	a		0.20	0.20		0.61	0.20	
7-10	0.20	2.04	a		5.10	0.92		0.71	0.20		3.06	0.41	
7-11	0.10	1.02	a		3.06	0.71		0.51	0.20		2.04	0.31	
7-12	0.20	2.04	0.31		5.10	1.02		0.92	0.41				
7-13		0.99	0.15		3.26	0.95		0.42	0.26		2.04	0.61	
7-14		0.80	0.06		0.88	0.05		0.36	0.20		1.73	0.42	
7-17		0.72	0.05		1.53			0.23	0.10		0.99	0.06	
7-18		0.45	0.03		0.91			0.10	0.08		0.56	0.05	
7-19		0.31	0.02		4.08	1.94		0.10	0.06		0.01	0.30	
7-20		2.24	0.62		1.83	0.46		0.15	0.10		0.29	0.03	
7-21		1.01	0.42		0.19	0.66		0.43	0.40	0.33	2.55	2.55	
7-22		0.62	0.24		1.43	0.27		0.23	0.20		1.01	0.58	
7-25		0.29	0.03		1.01			0.13	0.07		0.45	0.03	
7-26		0.85	0.44		3.06	1.43	1.01	0.60	0.58	0.51	0.95	0.35	
7-27		0.93	0.38		2.24	0.68	0.47	0.41	0.29	0.52	1.33	0.88	0.71
7-28		0.45	0.20		1.12	0.23	0.09	0.18	0.20	0.32	0.51	0.20	
7-31		0.20	0.02		0.70			0.09	0.04		0.17		
8-1		0.76	0.08		1.22			0.10	0.04		0.33		
8-3	0.20	1.43	0.75		3.77	1.94	1.12	0.91	0.84	0.66	0.91	0.39	
8-4	0.10	1.33	0.73		2.55	1.01	1.12	0.45	0.33	0.73	1.83	1.22	0.36
8-7	0.97	1.53	0.54		1.83	0.27	0.10	0.20	0.10	0.20	0.10	0.03	
8-8	0.80	1.12	0.44		0.99	0.09		0.09	0.08	0.07	0.18	0.06	
8-9	0.34	0.83	0.53		2.45	1.12	1.63	0.06	0.09	0.10	0.01		
8-10	0.19	0.61	0.39		0.90	0.39	0.31	0.20	0.20	0.27	0.32	0.21	

Table B-5. Discharge of tile drains on Hullinger farm in 1972. A blank in the data indicates no flow (Continued).

	Drain[b]											
Date	3N	4N	4M	4S	5N	5M	5S	5AN	5AM	5AS	6N	6M	6S
8-11	0.75	3.57	2.34	0.58	1.33	0.48	0.31	0.09	0.10	0.10	0.01	0.03	
8-15		0.05	0.20					0.01	0.01				
8-16		0.83	0.67	0.47				0.01	0.06				
8-17		0.90	0.10	0.01	1.73	0.76	0.39	0.14	0.06		0.02		
8-18	0.29	1.02	0.99		1.73	0.41	0.31	0.27	0.10		1.22	0.33	
8-21	0.09	1.12	0.45		1.83	0.10		0.25	0.09		1.22	0.10	
8-22	0.02	0.87	0.43		1.22	0.07		0.20	0.07		0.75	0.07	
8-24		0.42	0.36		1.33	0.25		0.10	0.20		0.76	0.10	
8-25		1.43	1.12		1.22	0.19		0.12	0.07		0.31	0.04	
8-28		0.09	0.15		0.16			a	a				
8-30		0.52	0.60		2.45	1.12			0.07		0.05	a	
8-31		1.73	1.33		1.94	0.55		0.22	0.15		0.55	0.11	
9-1		2.04	1.22		2.34	0.43		0.23	0.11		0.64	0.06	
9-2		1.43	0.97		1.22	0.22		0.12	0.07		0.19	a	
9-3		0.82	0.68		0.72	0.03		0.05	0.04		a		
9-4		0.43	0.39		0.25			a	a				
9-5		0.69	0.56		1.33	0.41	a	0.15	0.14		0.14	0.06	
9-7	0.47	0.57	0.54		0.41			0.02	0.02				
9-8	0.21	1.02	0.20		0.97			0.03					
9-11		0.08	0.06		0.06								
9-12			0.03										
9-13		0.44	0.40		0.91	0.09							
9-14		0.38	0.24		0.82	0.04			0.07				
9-15	a	0.74	0.18		0.87			0.05	0.02				
9-16		1.02	0.31		1.02			0.06	0.02				
9-22		0.10	0.03		0.01								

[a] Indicates measurable flow less than 0.01 m^3/hr. A blank indicates no flow from the drain on that date.

[b] Drains not listed had no flow in 1972.

Table B-6. Discharge of tile drains on Hullinger farm in 1973.

(m^3/hr)

	Drain[b]													
Date	1N	1M	2N	2M	3N	3M	4N	4M	5N	5M	5AN	5AM	6N	6M
6-18							1.63	1.02	1.53	0.20	0.20	0.10	0.71	0.10
6-19							1.73	1.12	1.22	0.10	0.10	0.10	0.51	0.10
6-20	1.22	0.31	2.24	0.82	3.87	1.02	2.85	1.63	1.02	0.20	0.10	0.10	0.41	0.10
6-21	0.31		0.61	0.20	1.22	0.20	1.63	1.12	1.12	0.10	0.10	0.10	0.61	0.10
6-22			0.10		0.61	0.10	1.73	1.02	2.55	0.20	0.31	0.10	1.33	0.10
6-25	0.10		0.61		2.24		0.51	0.41	1.02		0.20	0.10	0.92	0.10
6-26	1.22		3.06		4.59		1.43	0.61	1.43	0.71	0.20	0.10	1.53	0.31
6-27	0.10		0.51		1.53		1.22	0.61	1.22	0.10	0.20	0.10	0.92	0.20
6-28					0.82		0.71	0.41	0.82		0.10	0.10	0.51	0.10
6-29							0.41	0.20	0.71		0.10	0.10	0.31	0.10
7-2					0.51		0.51	0.10	1.02		0.20	0.10	0.71	0.10
7-3							0.10	a	0.82		0.10	0.10	0.31	a
7-4							0.10	a	0.61		0.10	0.10	0.51	0.20
7-5			0.51		2.65		0.92	0.20	1.12		0.20	0.10	1.22	0.31
7-9								a	0.20		a	a	0.10	
7-12									0.10				0.10	
7-13					1.83		3.06	1.83	2.24	0.10	0.10	0.10	0.71	0.10
7-16	1.02		1.02		2.65		2.65	1.12	2.85	0.41	0.41	0.20	1.94	0.51
7-17	1.22		1.22		2.65		2.55	1.02	2.65	0.31	0.41	0.20	1.83	0.41
7-18	1.02		0.82		1.83		1.73	0.82	1.73	0.20	0.31	0.20	1.12	0.31
7-19			1.03		2.24		2.24	0.82	2.24	0.20	0.31	0.20	1.33	0.31
7-20			1.53		2.65		2.55	1.12	4.08	0.82	0.31	0.20	1.73	0.51
7-24	1.02		1.53		2.65		2.14	0.82	2.34	0.31	0.31	0.20	1.53	0.41
7-25	0.82		0.82		2.24		1.94	0.71	2.14	0.20	0.31	0.20	1.33	0.31
7-26	0.20		0.10		1.53		1.43	0.61	1.83	0.31	0.41	0.20	3.57	0.92
7-27					0.82		1.02	0.51	1.43	0.10	0.20	0.10	1.33	0.31
7-30					0.20		0.41	0.31	0.51		0.10	a	0.51	a
7-31					0.31		0.61	0.31	1.02		0.31	0.10	0.82	0.10
8-1					1.02		1.33	0.51	1.73	0.10	0.20	0.10	1.02	0.20
8-2			0.31		1.22		1.43	0.51	1.63	0.10	0.20	0.10	1.33	0.31

Table B-6. Discharge of tile drains on Hullinger farm in 1973 (Continued).
(m^3/hr)

	Drain[b]													
Date	1N	1M	2N	2M	3N	3M	4N	4M	5N	5M	5AN	5AM	6N	6M
8-6					0.31		0.61	0.20	0.61		0.10	a	0.20	
8-7					0.20		0.61	0.20	0.51		0.10		0.10	
8-8	0.10		0.31		2.65		0.82	0.20	0.41		0.10	a	0.41	
8-9			0.20		2.24	0.51	4.18	3.26	3.47	1.22	0.20	0.10	0.41	
8-10					1.02		1.94	1.63	1.73	0.51	0.31	0.20	1.02	0.51
8-13					1.22		2.85	0.82	5.00	0.41	0.71	0.20	3.98	0.41
8-14					1.53		3.57	0.82	5.40	0.51	0.82	0.20	4.49	0.41
8-15					1.83		3.57	0.92	5.71	0.41	0.92	0.20	4.49	0.41
8-16					2.24		3.77	0.92	5.81	0.41	0.82	0.20	4.69	0.41
8-17					1.83		3.26	0.92	4.59	0.31	0.71	0.20	3.57	0.31
8-20			0.61		4.59	0.41	7.65	3.36	4.18	0.41	0.51	0.20	4.08	0.61
8-21			1.02		3.06	0.31	3.87	2.45	4.69	1.33	0.82	0.41	4.89	1.73
8-22	0.51		0.82		2.65	0.10	3.47	1.83	3.98	0.82	0.61	0.31	3.67	1.12
8-23	0.20		0.82		2.65		2.65	1.43	3.26	0.61	0.51	0.20	3.16	1.02
8-27	0.10		0.51		1.83		2.96	0.82	3.36	0.41	0.51	0.20	3.57	1.02
8-28					1.53		2.14	0.61	2.65	0.20	0.41	0.20	2.85	0.61
8-29					1.22		1.83	0.51	2.34	0.10	0.41	0.10	2.34	0.51
9-3					1.53		2.24	0.41	2.24		0.31	0.10	1.73	0.20
9-4					1.53		1.83	0.31	2.04		0.20	0.10	1.33	0.20
9-5	0.51		1.53	a	2.65		1.73	0.41	1.73		0.20	0.10	1.22	0.10
9-6			1.53	a	4.59	0.31	5.10	3.06	3.16	0.41	0.31	0.10	1.22	0.20
9-7	0.82		1.83		3.98	0.41	3.87	2.04	2.96	0.31	0.20	0.10	1.33	0.20
9-12			1.83		3.47		3.26	1.22	2.65	0.20	0.31	0.10	1.02	0.10
9-13			1.22		3.06		3.06	1.12	2.65	0.20	0.31	0.10	1.02	0.10
9-14			0.82		2.65		2.96	1.02	2.55	0.10	0.31	0.10	0.92	0.10

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[a] Indicates measurable flow less than 0.01 m^3/hr. A blank indicates no flow from the drain on that date.

[b] Drains not listed had no flow in 1973.

Table B-7. Water table depth and elevation at selected piezometers on Hullinger farm in 1972.

Date	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)
	1[b]		2		3		4	
4-21	2.05	0.94	1.95	0.95	2.16	0.94	1.95	2.34
5-5	2.10	0.89	1.99	0.91	2.21	0.89	2.01	2.28
6-7	0.80	2.19	0.87	2.03	1.16	1.94	1.09	3.20
7-4	1.70	1.29	1.60	1.30	1.82	1.28	1.54	2.75
7-11	1.22	1.77	1.19	1.71	1.44	1.66	1.09	3.20
7-18	1.26	1.73					1.25	3.04
7-19			1.33	1.57	1.57	1.53		
7-27	1.31	1.68	1.27	1.63	1.52	1.58	1.21	3.08
8-4	1.19	1.80					1.13	3.16
8-10	1.20	1.79					1.21	3.08
8-18	1.47	1.52	1.36	1.54	1.58	1.52	1.30	2.99
8-25	1.34	1.65	1.26	1.64			1.33	2.96
8-26					1.34	1.76		
8-28	1.53	1.46	1.43	1.47	1.65	1.45	1.43	2.86
9-2	0.98	2.01	0.94	1.96	1.24	1.86	1.03	3.26
9-11	1.40	1.59	1.32	1.58	1.55	1.55	1.28	3.01
9-22	1.10	1.89	1.09	1.81	1.34	1.76	1.24	3.05
9-29	1.41	1.58	1.34	1.56	1.58	1.52	1.26	3.03
10-9	0.94	2.05	1.00	1.90	1.28	1.82	1.04	3.25
	5		6		7		8	
4-21	1.93	2.34	2.06	2.31	1.70	2.74	2.03	2.68
5-5	1.99	2.28	2.11	2.26	1.76	2.68	2.09	2.62
6-7	1.13	3.14			0.84	3.60	1.30	3.41
7-4	1.52	2.75	1.64	2.73	1.29	3.15	1.60	3.11
7-11	1.12	3.15	1.29	3.08	0.82	3.62		
7-18	1.26	3.01	1.40	2.97	1.01	3.43	1.36	3.35
7-27	1.22	3.05	1.37	3.00	0.96	3.48	1.33	3.38
8-4	1.16	3.11	1.30	3.07	0.88	3.56	1.24	3.47
8-10	1.19	3.08	1.33	3.04	0.99	3.45	1.30	3.41
8-18	1.25	3.02	1.36	3.01	1.05	3.39	1.32	3.39
8-25	1.30	2.97			1.05	3.39	1.32	3.39
8-28	1.40	2.87			1.17	3.27		
9-2	1.05	3.22			0.88	3.56	1.18	3.53
9-11	1.27	3.00	1.41	2.96	1.04	3.40	1.35	3.36
9-16							1.14	3.57
9-22	1.25	3.02	1.39	2.98	1.02	3.42		
9-29	1.29	2.98	1.44	2.93	1.02	3.42	1.41	3.30
10-9	1.11	3.16	1.29	3.08	0.86	3.58	1.27	3.44

Table B-7. Water table depth and elevation at selected piezometers on Hullinger farm in 1972 (Continued).

Date	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)
	9		10		11		12	
4-21	2.02	4.64	2.05	4.57	2.37	4.59	2.15	5.33
5-5	2.07	4.59	2.09	4.53	2.41	4.55	2.20	5.28
6-7	1.08	5.58	1.01	5.61	1.42	5.54	1.11	6.37
7-4	1.52	5.14	1.53	5.09			1.57	5.91
7-11	0.90	5.76	0.96	5.66			0.89	6.59
7-18	1.22	5.44	1.24	5.38			1.25	6.23
7-27	1.19	5.47	1.17	5.45			1.29	6.19
7-28					1.51	5.45		
8-4	1.12	5.54	1.02	5.60	1.32	5.64	1.26	6.22
8-10	1.30	5.36	1.26	5.36	1.49	5.47	1.45	6.03
8-18	1.07	5.59	1.05	5.57	1.37	5.59	1.09	6.39
8-25	1.21	5.45	1.16	5.46	1.52	5.44	1.26	6.22
8-28	1.38	5.28	1.38	5.24			1.42	6.06
9-2	1.29	5.37	1.29	5.33	1.48	5.48	1.38	6.10
9-11	1.41	5.25	1.39	5.23	1.63	5.33	1.52	5.96
9-16					1.50	5.46		
9-22	1.45	5.21	1.43	5.19			1.58	5.90
9-29	1.46	5.20	1.43	5.19	1.72	5.24	1.59	5.89
10-9	1.42	5.24	1.39	5.23	1.69	5.27	1.56	5.92
	13		14		15		16	
4-21	2.06	5.33	2.41	4.98	2.21	2.22		
5-5	2.11	5.28	2.47	4.92	2.43	2.00		
6-7	0.84	6.55	1.40	5.99	1.57	2.86		
7-4	1.47	5.92	1.80	5.59	1.80	2.63		
7-11	0.84	6.55	1.30	6.09	1.55	2.88		
7-18	1.16	6.23	1.52	5.87	1.62	2.81		
7-27	1.16	6.23	1.50	5.89			1.20	3.88
8-4	1.09	6.30	1.44	5.95	1.51	2.92	1.13	3.95
8-10	1.31	6.08	1.62	5.77	1.48	2.95	1.17	3.91
8-18	1.05	6.34	1.44	5.95	1.45	2.98	1.15	3.93
8-25	1.15	6.24	1.55	5.84			1.07	4.01
8-28	1.33	6.06						
9-2	1.27	6.12	1.58	5.81			1.09	3.99
9-11	1.40	5.99	1.73	5.66	1.59	2.84	1.24	3.84
9-16			1.63	5.76			1.16	3.92
9-22	1.46	5.93			1.61	2.82		
9-29	1.46	5.93	1.82	5.57	1.68	2.75	1.29	3.79
10-9	1.44	5.95	1.80	5.59	1.58	2.85	1.25	3.83

Table B-7. Water table depth and elevation at selected piezometers on Hullinger farm in 1972 (Continued).

Date	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)
	17		18		19		20	
4-21					2.40	5.28	1.92	3.23
5-5					2.45	5.23	1.99	3.16
5-26							1.67	3.48
6-7					1.55	6.13	1.46	3.69
7-5							1.52	3.63
7-11					1.39	6.29		
7-18					1.53	6.15	1.40	3.75
7-27					1.48	6.20		
7-28	1.01	4.89	1.16	5.74			1.35	3.80
8-4	0.97	4.93	1.11	5.79	1.42	5.26	1.26	3.89
8-10	1.03	4.87	1.20	5.70	1.52	6.16	1.30	3.85
8-18	1.03	4.87	1.22	5.68	1.50	6.18	1.25	3.90
8-25	1.05	4.85	1.30	5.60	1.55	6.13	1.23	3.92
9-2	1.01	4.89	1.28	5.62	1.57	6.11	1.25	3.90
9-11	1.13	4.77	1.46	5.44	1.72	5.96	1.06	4.09
9-16	1.07	4.83	1.35	5.55	1.63	6.05	1.32	3.83
9-29	1.23	4.67	1.53	5.37	1.84	5.84	1.49	3.66
10-9	1.23	4.67	1.53	5.37	1.81	5.87	1.46	3.69
	21		22		23		24	
4-21	2.00	4.01			2.27	5.20		
5-5	2.07	3.94			2.33	5.14		
6-7	1.45	4.56			1.58	5.89		
7-4	1.52	4.49						
7-11	1.35	4.66			1.33	6.14		
7-18	1.34	4.67			1.43	6.04		
7-28	1.26	4.75	1.18	5.66	1.35	6.12	1.91	3.39
8-4	1.16	4.85	1.03	5.81	1.20	6.27	1.80	3.50
8-10	1.23	4.78	1.16	5.68	1.34	6.13	1.85	3.45
8-18	1.23	4.78	1.50	5.34	1.34	6.13	1.67	3.63
8-25	1.26	4.75	1.26	5.58	1.44	6.03		
8-28							1.86	3.44
9-2	1.25	4.76	1.26	5.58	1.46	6.01	1.72	3.58
9-11	1.38	4.63	1.41	5.43	1.62	5.85	1.89	3.41
9-16	1.32	4.69	1.33	5.51	1.53	5.94		
9-22							1.97	3.33
9-29	1.53	4.48	1.55	5.29	1.76	5.71	2.04	3.26
10-9	1.50	4.51	1.51	5.33	1.71	5.76	2.02	3.28

Table B-7. Water table and elevation at selected piezometers on Hullinger farm in 1972 (Continued).

Date	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)
	25		26		27		28	
4-21					2.78	5.13	2.51	5.80
5-5					2.83	5.08	2.56	5.75
6-7					2.24	5.67	1.69	6.62
7-5					2.25	5.66	1.80	6.51
7-11					2.10	5.81	1.49	6.82
7-18					2.14	5.77	1.61	6.70
7-28	1.69	4.62	1.65	5.38	1.99	5.92	1.55	6.76
8-4	1.61	4.70	1.58	5.45	1.91	6.00	1.42	6.89
8-10	1.67	4.64	1.66	5.37	1.99	5.92	1.60	6.71
8-18	1.67	4.64	1.74	5.29	2.10	5.81	1.55	6.76
8-25							1.60	6.71
8-28	1.78	4.53	1.83	5.20	2.18	5.73		
9-2	1.70	4.61	1.76	5.27	2.13	5.78	1.67	6.64
9-11	1.81	4.50	1.89	5.14	2.24	5.67	1.80	6.51
9-16							1.70	6.61
9-22	1.88	4.43	1.93	5.10	2.27	5.64		
9-29	1.98	4.33	2.01	5.02	2.35	5.56	1.96	6.35
10-9	1.98	4.33	1.99	5.04	2.31	5.60	1.85	6.46

[a] Elevation above mean sea level is value given plus 1600 m.

[b] Piezometer identification number, see Table 6.

Table B-8. Water table depth and elevation at selected piezometers on Hullinger farm in 1973.

Date	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)
	1[b]		2		3		4	
6-18	0.88	2.11	0.81	2.08	1.04	2.06	0.98	3.31
6-25	1.19	1.80	1.11	1.79	1.33	1.77	1.19	3.10
7-2	0.71	2.27	0.79	2.11	1.08	2.02	1.02	3.27
7-9	1.32	1.66	1.24	1.66	1.46	1.64	1.30	2.99
7-16	0.24	2.75	0.37	2.52	0.71	2.39	0.59	3.71
7-25	0.44	2.54	0.51	2.39	0.79	2.31	0.71	3.59
7-30	1.20	1.78	1.13	1.76	1.36	1.74	1.15	3.14
8-6	1.04	1.95	1.00	1.89	1.23	1.86	1.10	3.19
8-13	0.97	2.01	0.96	1.94	1.19	1.90	0.95	3.35
8-20	0.57	2.42	0.59	2.31	0.85	2.25	0.75	3.54
8-27	0.67	2.31	0.68	2.22	0.94	2.16	0.72	3.58
9-3	0.72	2.26	0.77	2.12	1.06	2.04	0.73	3.57
9-14	0.64	2.35	0.66	2.24	0.92	2.18	0.76	3.54
	5		6		7		8	
6-18	0.85	3.42	1.21	3.16	0.80	3.64	1.11	3.60
6-25	1.19	3.08	1.37	3.00	0.98	3.46	1.30	3.42
7-2	1.08	3.19	1.30	3.07	0.83	3.61	1.20	3.51
7-9	1.28	2.99	1.43	2.94	1.09	3.35	1.39	3.33
7-16	0.74	3.53	1.10	3.26	0.38	4.06	0.89	3.82
7-25	0.84	3.43	1.16	3.20	0.60	3.84	1.02	3.69
7-30	1.17	3.10	1.36	3.01	0.93	3.51	1.28	3.43
8-6	1.13	3.14	1.33	3.04	0.91	3.53	1.25	3.46
8-13	1.00	3.27	1.24	3.12	0.65	3.79	1.06	3.65
8-20	0.82	3.45	1.13	3.24	0.49	3.95	0.92	3.80
8-27	0.83	3.44	1.16	3.20	0.50	3.94	0.96	3.76
9-3	0.86	3.41	1.19	3.17	0.53	3.91	1.00	3.71
9-14	0.87	3.40	1.18	3.19	0.52	3.92	0.98	3.73
	9		10		11		12	
6-18	1.18	5.49	1.19	5.43	1.45	5.51	1.23	6.24
6-25	1.22	5.44	1.21	5.41	1.48	5.48	1.22	6.25
7-2	1.17	5.49	1.14	5.48	1.44	5.52	1.18	6.30
7-9	1.36	5.30	1.37	5.25	1.63	5.33	1.40	6.08
7-16	1.06	5.60	0.98	5.63	1.32	5.64	1.10	6.37
7-25	1.13	5.53	1.08	5.54	1.36	5.60	1.19	6.29
7-30	1.28	5.38	1.26	5.36	1.55	5.41	1.33	6.15

Table B-8. Water table depth and elevation at selected piezometers on Hullinger farm in 1973 (Continued).

Date	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)
8-6	1.29	5.37	1.29	5.33	1.56	5.40	1.35	6.12
8-13	0.47	6.19	0.66	5.96	0.99	5.96	0.51	6.97
8-20	0.85	5.81	0.88	5.74	1.17	5.79	0.82	6.65
8-27	0.88	5.78	0.89	5.73	1.20	5.76	0.86	6.62
9-3	1.04	5.62	1.06	5.56	1.34	5.62	1.09	6.39
9-14	1.11	5.55	1.09	5.52	1.37	5.59	1.20	6.28
	13		14		15		16	
6-18	1.11	6.28	1.52	6.15	1.37	3.05	1.13	3.95
6-25	1.10	6.29	1.46	6.21	1.49	2.94	1.19	3.89
7-2	1.05	6.34	1.41	6.26	1.48	2.95	1.20	3.88
7-9	1.28	6.11	1.59	6.08	1.56	2.87	1.24	3.84
7-16	0.96	6.43	1.32	6.34	1.33	3.10	1.08	4.00
7-25	1.06	6.33	1.40	6.27				
7-30	1.21	6.18	1.53	6.14	1.51	2.92	1.19	3.89
8-6	1.24	6.15	1.56	6.10	1.50	2.93	1.19	3.89
8-13	0.44	6.95	1.05	6.62	1.43	3.00	1.09	3.99
8-20	0.75	6.64	1.19	6.48	1.34	3.09	0.99	4.09
8-27	0.77	6.62	1.20	6.47	1.38	3.05	1.08	3.99
9-3	0.98	6.41	1.35	6.32	1.42	3.00	1.12	3.96
9-14	1.09	6.30	1.43	6.24	1.37	3.06	1.09	3.98
	17		18		19		20	
6-18	1.03	4.87	1.26	5.64	1.50	6.18	1.27	3.88
6-25	1.06	4.84	1.29	5.61	1.51	6.16	1.32	3.83
7-2	1.08	4.82	1.28	5.62	1.51	6.17	1.36	3.79
7-9	1.11	4.79	1.39	5.51	1.61	6.07	1.36	3.79
7-16	1.04	4.86	1.16	5.74	1.42	6.26	1.27	3.88
7-25	1.00	4.90	1.22	5.68	1.45	6.23		
7-30	1.07	4.83	1.35	5.55	1.56	6.12	1.33	3.82
8-6	1.07	4.83	1.35	5.55	1.58	6.10	1.35	3.81
8-13	0.99	4.91	1.03	5.87	1.37	6.31	1.28	3.88
8-20	0.93	4.97	1.11	5.79	1.37	6.31	1.16	3.99
8-27	0.95	4.95	1.09	5.81	1.36	6.32	1.28	3.87
9-3	1.01	4.88	1.22	5.68	1.48	6.20	1.33	3.82
9-14	0.99	4.91	1.24	5.66	1.52	6.16	1.30	3.85

Table B-8. Water table depth and elevation at selected piezometers on Hullinger farm in 1973 (Continued).

Date	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)	Depth (m)	Elev.[a] (m)
	21		22		23		24	
6-18	1.27	4.74	1.22	5.62	1.36	6.11	1.76	3.54
6-25	1.32	4.69	1.27	5.57	1.41	6.06	1.85	3.45
7-2	1.35	4.66	1.29	5.56	1.43	6.05	1.84	3.46
7-9	1.38	4.63	1.35	5.49	1.49	5.98	1.93	3.37
7-16	1.24	4.76	1.17	5.67	1.30	6.18	1.78	3.52
7-25	1.27	4.74	1.19	5.65	1.34	6.13		
7-30	1.34	4.67	1.31	5.53	1.46	6.01	1.87	3.43
8-6	1.35	4.66	1.33	5.52	1.48	6.00	1.89	3.41
8-13	1.24	4.77	1.18	5.67	1.34	6.14	1.79	3.51
8-20	1.26	4.75	1.19	5.65	1.32	6.15	1.70	3.60
8-27	1.23	4.77	1.13	5.71	1.24	6.24	1.81	3.49
9-3	1.32	4.68	1.26	5.58	1.40	6.07	1.91	3.39
9-14	1.30	4.71	1.28	5.56	1.44	6.03	1.85	3.45
	25		26		27		28	
6-18	1.73	4.58	1.75	5.29	2.05	5.86	1.43	6.88
6-25	1.76	4.55	1.80	5.24	1.82	6.09	1.52	6.78
7-2	1.80	4.51	1.83	5.20	2.15	5.75	1.52	6.79
7-9	1.83	4.48	1.85	5.18	2.17	5.74	1.62	6.69
7-16	1.73	4.58	1.73	5.30	2.01	5.89	1.35	6.96
7-25	1.71	4.60	1.69	5.35	1.98	5.92	1.42	6.89
7-30	1.77	4.54	1.79	5.25	2.09	5.81	1.56	6.75
8-6	1.80	4.51	1.83	5.21	2.14	5.76	1.59	6.72
8-13	1.73	4.58	1.76	5.27	2.10	5.80	1.47	6.84
8-20	1.78	4.53	1.80	5.24	2.12	5.79	1.36	6.95
8-27	1.73	4.58	1.71	5.32	1.97	5.93	1.19	7.12
9-3	1.80	4.51	1.81	5.22	2.12	5.79	1.47	6.84
9-14	1.80	4.51	1.83	5.20	2.18	5.72	1.63	6.68

[a] Elevation above mean sea level is value given plus 1600 m.

[b] Piezometer identification number, see Table 6.

Table B-9. EC of tile drain effluent on Hullinger farm in 1972.

(mmho/cm)

	Drain												
Date	3N	4N	4M	4S	5N	5M	5S	5AN	5AM	5AS	6N	6M	6S
6-28	2.0	1.4	2.2					1.8	2.2		1.6		
6-29	2.0	1.4	2.1		1.5	1.7		2.0	2.3		1.5		
6-30		1.4	2.0		1.6	1.6		2.0	2.1		1.7		
7-3					1.5	1.7							
7-5					1.7								
7-7					1.2	1.2		1.8	1.8		1.2	1.5	
7-10	1.9	1.3	2.3		1.4	1.6		1.8	2.2		1.3	1.7	
7-11	1.8	1.3	2.1		1.4	1.5		1.6	2.1		1.2	1.6	
7-12	1.8	1.2	2.2		1.3	1.6		1.7	2.2				
7-13		1.6	2.3		1.7	1.6		2.1	1.9		1.3	1.6	
7-14		1.2	2.1		1.4	1.5		1.6	2.1		1.3	1.9	
7-17		1.2	2.0		1.4			1.3	2.0		1.4	1.8	
7-18		1.3	2.2		1.5			1.7	2.1		1.4	1.8	
7-19		1.4	2.1		1.7	1.7		1.8	2.0		1.5	2.0	
7-20		1.3	2.1		1.7	1.8		1.8	2.0		1.5	1.9	
7-21		1.9	2.0		1.6	1.7		2.0	2.2	2.3	1.5	2.5	
7-22		1.4	2.1		1.5	1.6		1.8	1.9		1.5	1.9	
7-25		1.4	2.2		1.6			2.9	2.1		1.6	2.0	
7-26		1.5	1.8		1.7	1.9	1.9	2.9	2.1	2.4	1.7	1.9	
7-27		1.2	1.8		1.6	1.8	1.9	2.0	1.9	2.1	1.6	2.2	3.0
7-28		1.1	1.9		1.5	1.6	1.7	1.8	2.1	2.0	1.5	1.9	
7-31		1.3	1.8		1.4			2.1	1.8		1.7		
8-1		1.4	2.0		1.5			2.0	2.1		1.5		
8-3	1.7	1.3	1.8		1.7	1.8	1.8	2.7	2.8	2.2	1.6	1.8	
8-4	1.6	1.3	1.6		1.5	1.8	1.9	1.9	2.1	1.9	1.7	1.9	2.8
8-7	1.8	1.3	1.9		1.7	1.9	2.0	2.1	2.0	2.0	2.1	2.0	
8-8	2.1	1.4	2.1		1.9	2.1		2.4	2.4	2.3	1.9	2.0	
8-9	2.0	1.4	2.0		1.9	2.0	2.3	2.4	2.1	2.2	2.0		

Table B-9. EC of tile drain effluent on Hullinger farm in 1972 (Continued).

(mmho/cm)

	Drain												
Date	3N	4N	4M	4S	5N	5M	5S	5AN	5AM	5AS	6N	6M	6S
8-10	1.9	1.4	1.4		1.8	2.2	2.2	2.3	2.3	2.3	2.0	2.5	
8-11	2.2	1.6	2.3	2.9	2.0	2.2	2.2	2.5	2.5	2.4	2.0	2.9	
8-15		1.6	2.3					2.7	2.4				
8-16		1.7	2.3	3.1				2.7	2.5				
8-17		1.7	2.2	2.2	2.1	2.4	2.2	2.7	2.6		2.6		
8-18	2.5	1.7	2.2		2.0	2.4	2.4	2.6	2.6		2.4	2.8	
8-21	2.2	1.6	2.4		2.0	2.3		2.7	2.5		1.8	2.5	
8-22	2.2	1.7	2.3		1.9	2.2		2.5	2.5		1.8	2.6	
8-24		1.6	2.3		1.9	2.4		2.6	2.5		1.8	2.5	
8-25		1.7	2.3		1.9	2.3		2.3	2.6		1.9	2.7	
8-28		1.7	2.2		2.0			2.4	2.3				
8-30		1.7	2.2		2.1	2.7			2.4		2.7	3.3	
8-31		1.7	2.4		2.0	2.3		2.5	2.6		2.0	2.4	
9-1		1.7	2.4		1.9	2.4		2.8	2.3		1.8	2.8	
9-2		1.2	2.1		2.0	2.4		2.7	2.3		2.1	2.5	
9-3		1.6	2.2		2.4	2.3		2.4	2.6		2.4		
9-4		1.6	2.2		2.0			2.7	2.7				
9-5		1.7	2.2		2.2	2.3	2.2	2.5	2.7		2.3	2.6	
9-7	2.4	1.7	2.4		2.1			2.6	2.6				
9-8	2.6	1.8	2.5		2.1			3.0					
9-11		1.8	2.6		1.7								
9-12			2.5										
9-13		1.9	2.6		2.4	2.5							
9-14		1.9	2.7		2.0	2.7			2.9				
9-15	2.3	1.8	2.7		2.2			2.0	2.7				
9-16		1.8	2.7		2.1			2.9	3.0				
9-22		1.7	2.4		2.3								
Average	2.1	1.5	2.2	2.7	1.8	2.0	2.2	2.3	2.3	2.2	1.8	2.2	2.9

Table B-10. EC of tile drain effluent on Hullinger farm in 1973.

(mmho/cm)

	Drain													
Date	1N	1M	2N	2M	3N	3M	4N	4M	5N	5M	5AN	5AM	6N	6M
6-18							1.7	1.7	2.0	2.3	2.2	2.8	1.7	2.7
6-19							1.8	2.2	2.1	2.2	2.3	2.9	1.8	2.6
6-20	2.7	3.6	2.8	3.1	2.1	2.4	1.8	2.3	2.0	2.3	2.3	2.8	1.8	2.7
6-21	2.6		2.7	3.1	2.0	2.1	1.7	2.1	2.0	2.2	2.2	2.8	1.8	2.7
6-22			2.9		2.0	2.4	1.7	2.2	2.0	2.2	2.3	2.8	1.7	2.6
6-25	2.7		2.7		2.0		1.8	2.2	1.9		2.2	2.6	1.6	2.3
6-26	2.8		2.6		2.0		1.7	2.3	2.0	2.3	2.2	2.7	1.8	2.4
6-27	2.8		2.6		2.0		1.7	2.3	2.0	2.8	2.2	2.7	1.8	2.4
6-28					2.1		1.7	2.3	2.1		2.2	2.7	1.8	2.5
6-29							1.7	2.3	2.0		2.3	2.8	1.8	2.5
7-2					1.5		1.7	2.1	1.9		2.3	2.7	1.7	2.4
7-3							1.7	2.3	1.9		2.1	2.6	1.7	2.4
7-4							1.6	2.1	1.8		2.1	2.6	1.4	1.9
7-5			2.6		2.0		1.6	2.4	1.9		2.2	2.8	1.8	2.5
7-9									1.9				1.9	
7-12									2.1				2.0	
7-13					2.1		1.8	2.5	2.1	2.4	2.2	2.9	1.9	2.5
7-16	2.4		2.2		1.7		1.7	2.3	1.9	2.4	2.3	2.7	1.8	2.5
7-17	2.5		2.3		1.6		1.8	2.3	1.9	2.3	2.2	2.7	1.7	2.4
7-18	2.5		2.3		1.8		1.8	2.3	2.0	2.3	2.2	2.7	1.8	2.3
7-19			2.3		1.8		1.7	2.3	1.9	2.2	1.9	2.3	1.8	2.4
7-20			2.4		2.0		1.7	2.3	1.9	2.3	2.1	2.3	1.8	2.4
7-24	2.3		2.1		1.9		1.7	2.3	1.9	2.3	2.2	2.6	1.8	2.2
7-25	2.3		2.1		1.7		1.7	2.3	1.8	2.2	2.0	2.5	1.7	2.2
7-26	2.3		2.0		1.8		1.6	2.1	1.9	2.3	2.0	2.5	1.6	2.1
7-27					1.7		1.6	2.1	1.8	2.2	2.1	2.5	1.7	2.1
7-30					1.8		1.6	2.3	1.7		1.8		1.6	
7-31					1.7		1.6	2.2	1.7		2.1	2.5	1.8	2.1
8-1					1.7		1.6	2.2	1.8	2.0	2.1	2.5	1.6	2.1
8-2			2.0		1.6		1.6	2.3	1.6	2.0	2.0	2.5	1.6	2.1

Table B-10. EC of tile drain effluent on Hullinger farm in 1973 (Continued).

(mmho/cm)

	Drain													
Date	1N	1M	2N	2M	3N	3M	4N	4M	5N	4M	5AN	5AM	6N	6M
8-6					1.8		1.7	2.3	1.8		1.9		1.9	
8-7					1.6		1.6	2.3	1.8		2.1		1.7	
8-8	2.9		2.1		1.7		1.6	2.3	1.8		2.2		1.9	
8-9			2.7		1.8	2.3	1.6	2.3	1.7	2.1	2.2	2.5	1.9	
8-10					1.6		1.7	2.2	1.6	1.9	1.8	2.2	1.7	2.3
8-13					1.6		1.5	2.1	1.5	1.8	2.0	2.4	1.6	2.1
8-14					1.7		1.7	2.2	1.7	2.1	2.0	2.4	1.7	2.1
8-15					1.7		1.6	2.2	1.7	2.0	1.9	2.4	1.6	2.1
8-16					1.7		1.6	2.2	1.6	2.0	1.8	2.3	1.6	2.0
8-17					1.8		1.6	2.2	1.7	2.0	1.8	2.4	1.6	2.0
8-20			2.5		2.0	2.2	1.7	2.3	1.6	1.9	1.8	2.3	1.6	2.0
8-21			2.5		1.9	2.2	1.7	2.2	1.7	2.2	1.6	2.4	1.7	2.2
8-22	2.5		2.4		1.8	2.2	1.7	2.2	1.7	2.1	1.8	2.3	1.7	2.2
8-23	2.5		2.3		1.6		1.7	2.2	1.6	2.1	1.7	2.2	1.6	2.0
8-27	2.2		2.0		1.7		1.6	2.1	1.6	2.0	1.8	2.1	1.6	2.0
8-28					1.7		1.6	2.1	1.6	1.9	1.8	2.2	1.7	2.0
8-29					1.7		1.6	2.2	1.7	1.9	1.8	2.2	1.7	2.0
9-3					1.7		1.6	2.3	1.6		1.8	2.2	1.7	1.9
9-4					1.6		1.6	2.3	1.7		1.8	2.2	1.8	2.0
9-5	2.8		2.5	3.7	1.7		1.6	2.3	1.7		1.8	2.2	1.8	2.0
9-6			2.4	3.5	1.9	2.4	1.6	2.3	1.6	1.9	1.8	2.2	1.8	2.0
9-7	2.5		2.3		1.9	2.2	1.7	2.3	1.7	1.9	1.9	2.2	1.8	2.0
9-12			2.2		1.8		1.7	2.3	1.7	1.9	1.9	2.3	1.9	2.1
9-13			2.1		1.9		1.8	2.3	1.7	1.9	1.9	2.3	1.9	2.2
9-14			2.1		1.7		1.8	2.2	1.7	1.9	1.9	2.2	1.9	2.2
Average	2.5	3.6	2.4	3.4	1.8	2.3	1.7	2.2	1.8	2.1	2.0	2.5	1.7	2.2

Table B-11. Electrical conductivity of samples withdrawn from ceramic cups (106 cm depth) in commercial fertilizer plots treated with $Ca(NO_3)_2$ in 1972.

(mmho/cm)

	Date								
	7-14	7-22	7-28	8-4	8-10	8-19	8-24	9-6	9-18
Alfalfa 3N1	4.0	3.3	3.4	2.6	4.1	3.8	4.0	3.7	---
Alfalfa 3N2	4.6	3.5	3.8	3.6	4.0	4.2	4.3	3.5	5.0
Alfalfa 3M2	3.4	---	3.6	---	4.4	2.9	4.6	4.4	---
Alfalfa 3S2	5.3	---	4.1	---	5.2	---	6.4	6.1	7.7
Alfalfa 4N1	1.7	2.0	1.8	1.5	1.9	5.4	2.7	3.0	2.8
Alfalfa 4N2	3.6	3.2	2.9	2.5	3.3	2.9	3.7	---	4.1
Alfalfa 4M1	3.9	2.8	2.2	2.7	4.1	4.0	4.1	---	4.5
Alfalfa 4M2	---	2.3	2.8	2.8	3.3	3.8	3.7	4.1	4.2
Alfalfa 4S1	3.9	3.5	---	3.3	3.8	4.2	4.4	---	4.6
Alfalfa 4S2	---	---	---	7.5	5.6	---	---	---	---
Corn 5N1	3.4	2.8	3.1	2.7	4.1	3.9	3.9	3.8	4.1
Corn 5N2	3.3	2.4	3.2	3.3	4.4	4.6	4.5	4.7	4.6
Corn 5M1	---	2.1	2.8	2.8	4.4	1.2	---	---	---
Corn 5M2	4.3	3.1	3.1	3.0	4.0	3.9	3.9	3.7	3.8
Corn 5S1	3.5	3.3	3.4	---	4.2	4.2	4.1	3.3	---
Corn 5S2	4.7	3.1	3.6	4.0	4.5	4.7	4.8	3.3	---
Corn 5AN1	2.7	2.3	3.4	---	3.1	3.4	3.1	2.8	2.8
Corn 5AN2	3.7	2.4	3.3	---	2.7	2.9	2.8	2.3	0.9
Corn 5AM1	3.8	2.9	3.0	2.9	4.5	4.3	4.3	4.1	4.3
Corn 5AM2	3.3	2.4	3.2	3.0	3.8	4.3	4.1	3.7	4.2
Corn 5AS1	3.6	2.4	2.8	---	3.4	3.5	3.5	3.7	3.6
Corn 5AS2	---	3.2	3.5	3.1	3.6	4.0	3.8	3.8	4.0
Corn 6N1	2.9	2.5	3.2	3.0	3.9	2.9	3.7	3.7	3.2
Corn 6N2	2.3	2.2	---	1.9	---	---	---	---	---
Corn 6M1	2.4	2.1	2.4	2.2	3.5	3.1	2.9	2.3	2.7
Corn 6M2	2.9	2.0	---	2.0	2.3	2.5	2.5	2.5	2.7
Corn 6S1	1.7	3.2	---	1.7	3.9	3.9	4.0	4.0	4.2
Corn 6S2	4.8	3.4	---	3.4	3.5	3.7	3.7	3.7	3.6

Table B-12. Electrical conductivity of samples withdrawn from ceramic cups (76 and 106 cm depths) in commercial fertilizer plots treated with NH_4NO_3 in 1973.

(mmho/cm)

	Date									
	76 cm depth					106 cm depth				
	7-17	7-30	8-10	8-23	9-5	7-17	7-30	8-10	8-23	9-5
Alfalfa 3M1	---	---	3.8	4.6	3.9	2.6	---	1.3	1.8	---
Alfalfa 3M2	3.2	4.3	4.7	4.7	4.4	2.2	---	4.1	3.5	3.7
Alfalfa 4N1	2.5	2.2	2.2	2.2	2.2	3.4	3.8	3.8	3.8	3.7
Alfalfa 4N2	4.2	4.2	4.2	4.1	3.7	4.0	2.5	4.3	4.4	4.4
Alfalfa 4M1	3.4	3.2	3.5	3.6	3.8	4.2	4.5	4.3	4.4	4.8
Alfalfa 4M2	4.3	2.3	2.8	3.3	3.1	3.2	---	1.8	2.3	1.8
Corn 5N1	3.3	3.3	3.3	3.3	3.2	3.7	---	3.7	4.0	4.1
Corn 5N2	3.2	3.3	3.2	3.3	3.3	3.5	3.7	3.8	3.9	4.0
Corn 5M1	2.8	---	3.0	2.9	2.6	2.8	2.8	2.8	2.8	2.7
Corn 5M1	4.2	4.2	4.3	4.3	4.3	3.1	---	3.0	3.2	4.0
Corn 5AN1	---	---	2.3	2.4	2.4	---	3.9	3.7	4.0	4.3
Corn 5AN2	2.2	2.6	2.3	2.3	2.3	2.2	1.9	2.1	2.3	2.4
Corn 5AM1	3.6	3.6	2.6	---	3.9	3.6	3.5	2.4	2.3	3.9
Corn 5AM1	3.5	3.5	3.2	3.7	3.1	---	---	2.8	1.8	2.8
Corn 6N1	3.0	3.0	2.9	3.0	3.3	5.1	4.1	4.2	4.1	4.1
Corn 6N2	3.9	3.9	4.0	3.2	3.0	2.6	2.7	2.8	2.3	2.5
Corn 6M1	---	---	---	---	---	---	---	3.3	4.1	4.3
Corn 6M2	2.3	0	2.2	2.2	2.2	---	---	2.7	2.5	2.3

Table B-13. Computations of EC derived from measurements with the 4-probe field system during 1972 field trials in Vernal.

Date	Time	Depth Interval (cm)											
		0-15	15-30	30-46	46-61	61-76	76-91	91-107	107-122	122-137	137-152	152-168	168-183
8-8	1540	1.0	1.1	1.36	1.67	2.19	1.54	1.51	.74	2.02	1.33	.27	.63
8-9	0700	.74	1.2	1.77	2.38	0.88	2.22	1.10	2.10	.90	.70	.63	.81
8-9	0935	1.57	1.85	1.43	1.80	1.23	1.45	.87	.80	1.02	.58	.56	.34
8-9	1150	1.60	1.81	1.39	1.82	1.19	1.56	.88	.97	1.10	.78	.37	.33
8-9	1655	1.73	1.85	1.46	1.74	1.18	1.37	.81	1.15	.97	1.01	.36	.52
8-10	0730	1.62	1.88	1.68	2.22	1.27	1.66	.80	1.28	.85	.47	1.09	.56
8-10	0810	1.86	2.01	1.50	1.88	1.11	1.32	1.00	.76	.75	.87	.37	.60
8-10	0915	1.57	1.70	1.90	1.83	1.16	1.29	1.16	1.18	.78	.87	.62	.53
8-10	1210	1.71	1.63	1.91	1.71	1.21	1.37	1.15	.82	.89	1.00	.84	.42
8-10	1610	1.73	1.62	1.89	1.71	1.20	1.17	1.06	1.19	.79	.88	.59	.42
8-11	0835	1.55	1.60	2.03	2.13	1.34	1.39	1.22	1.34	.95	1.15	.62	.69
8-11	1420	1.67	1.52	1.93	1.97	1.18	1.27	1.13	1.13	.95	.97	.47	.75
8-18	1400	1.23	2.28	2.00	3.12	2.51	3.29	2.88	1.51	.93	1.23	.79	.60
9-18	1700	.82	1.67	1.21	.78	.79	3.97	.68	2.64	2.24	.27	1.53	.47
9-19	0815	1.08	1.22	1.30	1.87	2.03	1.88	2.00	1.80	1.94	.55	1.25	1.33
9-19	1040	1.15	1.23	1.30	2.01	1.91	1.93	1.70	2.40	1.59	1.10	1.10	1.09
9-19	1150	1.75	1.86	1.85	2.14	1.73	1.73	1.21	1.28	.69	.74	.61	.74
9-19	1300	1.57	1.77	1.88	2.10	1.69	1.91	1.35	1.24	.89	.96	.55	.86
9-19	1400	1.67	1.88	1.92	2.16	1.78	1.83	1.54	1.34	.91	.98	.72	.78
9-19	1510	1.67	1.72	1.93	2.32	1.64	1.99	1.61	1.00	1.31	.90	.62	.94
9-19	1785	1.68	1.88	2.05	2.30	1.66	1.78	1.54	1.50	.85	1.08	.88	1.05
9-20	0740	1.61	1.79	1.85	2.70	1.76	2.13	1.62	1.92	1.30	.96	.93	.93
9-20	1100	1.54	1.63	1.84	2.41	1.63	1.76	1.59	1.96	1.09	.92	.75	1.03
9-20	1345	1.35	1.49	1.58	1.43	1.50	1.12	.88	1.30	.59	.73	.73	.52
9-20	1420	1.36	1.48	1.46	1.64	1.49	1.74	1.40	1.21	1.00	1.07	.92	.62
9-20	1535	1.41	1.54	1.53	1.67	1.52	1.90	1.36	1.51	.96	1.04	.78	.78
9-20	1733	1.35	1.50	1.62	3.69	1.52	2.15	1.22	1.52	1.07	1.06	1.13	.74
9-21	0805	1.09	1.47	1.47	1.95	1.56	1.82	1.41	1.98	1.35	.09	1.99	.63
9-21	1325	1.28	1.44	1.49	1.78	1.46	1.70	1.59	1.89	1.26	1.06	.99	.76

EC = K4P/Θ (500 Θ - 40) where K4P are in mmho/cm and Θ = water content (fraction).

Table B-14. Initial (6-28) and final (10-7) soil tests in plots 1972 for $N\text{-}NO_3$.

(ppm)

	30 cm		60 cm		90 cm		120 cm	
Plot	Initial	Final	Initial	Final	Initial	Final	Initial	Final
3N1	.7	4.4	1.0	4.3	.4	1.0	1.2	.6
3N2	1.1	2.1	.1	.4	2.2	.8	1.6	.6
3M2	.6	1.8	3.5	.6	.4	1.0	.6	5.5
3S1	1.3	1.0	1.6	.7	1.0	.6	1.5	.4
4N1	1.0	1.2	5.8	2.8	.8	.7	1.0	.7
4N2	5.1	4.6	60.6	2.8	2.1	.9	2.4	.8
4M1	9.5	4.4	70.1	40.4	.7	49.0	.5	13.8
4M2	28.2	3.5	119.9	2.0	2.3	12.8	1.2	.9
4S1	12.8	3.2	22.6	3.6	1.[illegible]	28.3	1.1	6.9
4S2	9.3	2.8	28.2	2.0	4.4	1.2	1.7	1.1
5N1	20.0	3.8	6.1	1.2	2.0	2.3	1.0	7.1
5N2	38.4	3.8	9.2	1.1	1.0	0	2.9	1.4
5M1	85.6	8.3	1.0	1.7	1.0	26.2	1.1	83.0
5M2	56.4	54.3	1.8	66.2	1.0	15.3	.2	21.4
5S1	19.4	2.6	18.0	4.4	2.2	7.5	1.0	18.6
5S2	55.8	3.6	.9	1.8	2.0	3.4	1.3	15.8
5AN1	15.4	70.5	.5	68.0	.9	24.8	1.4	104.5
5AN2	12.6	125.0	.9	87.0	1.2	56.8	2.5	78.2
5AM1	75.9	10.5	1.6	26.3	.8	28.7	1.6	18.0
5AM2	120.9	4.5	1.4	69.0	1.2	90.5	2.9	33.8
5AS1	15.0	112.2	.5	86.0	1.4	115.5	1.5	82.2
5AS2	7.0	75.8	1.6	.6	1.4	96.2	2.9	2.7
6N1	9.6	4.4	.5	.9	.2	1.2	5.1	3.4
6N2	.6	6.0	.4	.6	.1	1.2	.5	1.7
6M1	3.6	1.9	.1	1.0	.2	.9	.4	4.2
6M2	9.0	6.3	2.0	.9	.2	1.1	.3	.9
6S1	7.7	2.4	.3	.8	.1	.3	.3	.5
6S2	.4	.5	1.3	1.5	.9	1.2	1.3	1.6

Table B-15. Initial (6-20) and final (9-19) soil tests in plots 1973 for $N\text{-}NO_3$.

(ppm)

	30 cm		60 cm		90 cm		120 cm	
Plot	Initial	Final	Initial	Final	Initial	Final	Initial	Final
3M1	5.0	3.8	3.3	.6	.8	1.3	.4	.6
3M2	7.5	2.8	6.0	.6	3.6	.4	.5	.5
4N1	8.8	2.8	7.0	.4	.8	1.3	.4	.3
4N2	19.5	2.9	23.5	.8	.8	1.3	.5	.1
4M1	75.0	2.9	18.8	1.0	3.8	18.3	6.3	8.6
4M2	38.3	7.5	32.5	81.8	6.3	4.4	1.8	1.6
4S1	43.8	3.1	18.8	1.1	4.3	15.8	1.8	.5
4S2	20.0	2.0	21.3	1.5	4.3	4.3	1.9	.1
5N1	59.3	28.3	18.8	6.5	4.5	2.0	5.2	.3
5N2	41.3	28.3	19.3	6.4	5.3	2.3	5.4	1.3
5M1	165.0	38.3	36.8	63.0	32.5	4.5	9.0	1.6
5M2	163.8	34.5	20.5	62.0	16.8	24.0	32.5	10.5
5S1	144.3	26.8	10.8	99.5	9.6	20.3	35.0	5.1
5S2	92.5	9.3	22.5	38.8	11.1	10.0	20.3	12.4
5AN1	43.8	7.1	9.3	7.8	3.5	13.8	2.7	4.1
5AN2	74.0	7.8	47.8	8.3	7.0	4.3	3.4	1.6
5AM1	132.0	10.8	28.3	69.3	19.8	33.8	14.0	12.4
5AM2	142.5	14.5	29.3	69.5	40.0	47.5	26.4	28.5
5AS1	52.8	2.8	20.0	1.8	5.0	.8	6.2	1.5
5AS2	37.5	3.9	9.5	10.5	8.7	7.5	5.8	6.1
6N1	20.5	7.6	9.3	2.3	6.0	4.0	3.3	2.1
6N2	32.8	4.5	18.0	1.0	3.4	2.3	3.1	.5
6M1	28.0	3.5	13.8	2.0	5.8	.8	8.1	2.0
6M2	18.0	3.4	8.3	1.0	3.8	1.5	3.4	3.3
6S1	24.5	3.1	5.0	.8	4.3	.6	3.9	.4
6S2	24.5	3.0	6.3	1.0	5.5	.5	2.9	.8

Table B-16. N-NO_3 in commercial fertilizer plots treated with various rates of NH_4NO_3 collected from ceramic samplers in 1973 from 76 cm and 106 cm depths.

(ppm)

	Date									
	76 cm depth					106 cm depth				
	7-17	7-30	8-10	8-23	9-5	7-17	7-30	8-10	8-23	9-5
Alfalfa 3M1	---	---	0	5	1	1	---	0	0	---
Alfalfa 3M2	0	2	0	0	0	0	---	1	1	0
Alfalfa 4N1	1	0	0	0	0	0	0	0	0	0
Alfalfa 4N2	0	0	0	0	0	2	---	33	6	0
Alfalfa 4M1	1	1	1	1	0	4	3	---	17	42
Alfalfa 4M2	4	11	9	8	28	69	86	59	76	30
Corn 5N1	8	2	5	1	0	26	---	1	8	11
Corn 5N2	15	11	8	9	4	15	7	2	2	2
Corn 5M1	48	---	44	35	17	42	37	36	27	14
Corn 5M1	137	160	---	101	122	61	---	28	54	81
Corn 5AN1	---	---	5	6	8	---	3	22	35	56
Corn 5AN2	11	31	5	5	5	21	9	15	9	8
Corn 5AM1	133	100	62	---	109	129	105	48	38	83
Corn 5AM2	114	113	76	81	72	---	---	49	30	72
Corn 6N1	10	14	28	23	12	132	21	10	25	34
Corn 6N2	33	15	29	21	4	18	21	17	5	1
Corn 6M1	---	---	---	---	---	---	---	24	15	11
Corn 6M2	9	---	6	2	2	---	---	5	2	2

Table B-17. N-NO_3 in commercial fertilizer plots treated with various rates of $Ca(NO_3)_2$ collected from ceramic samplers (106 cm depth) in 1972.

(ppm)

	Date								
	7-14	7-22	7-28	8-4	8-10	8-19	8-24	9-6	9-18
Alfalfa 3N1	1	1	1	1	0	1	1	1	1
Alfalfa 3N2	1	0	0	0	0	1	3	0	1
Alfalfa 3M2	0	---	0	---	1	1	1	0	---
Alfalfa 3S1	1	---	1	---	0	---	1	1	1
Alfalfa 4N1	0	0	0	0	0	2	1	1	0
Alfalfa 4N2	0	0	0	0	0	0	1	---	0
Alfalfa 4M1	0	0	0	0	0	2	0	---	0
Alfalfa 4M2	---	0	1	0	0	12	3	4	11
Alfalfa 4S1	0	1	---	1	0	1	0	---	0
Alfalfa 4S2	---	41	---	19	3	---	---	---	---
Corn 5N1	0	0	1	33	83	71	70	75	69
Corn 5N2	0	0	7	52	82	91	82	65	35
Corn 5M1	---	0	1	12	94	1	---	---	---
Corn 5M2	0	0	6	0	21	19	15	44	40
Corn 5S1	0	19	15	---	102	109	50	62	---
Corn 5S2	0	3	1	5	21	10	50	59	---
Corn 5AN1	1	1	9	---	68	106	80	56	43
Corn 5AN2	0	2	10	---	10	60	49	7	0
Corn 5AM1	0	2	1	32	99	110	125	111	84
Corn 5AM2	15	1	10	16	16	23	25	21	20
Corn 5AS1	18	3	1	---	3	5	6	9	9
Corn 5AS2	---	8	6	25	40	46	48	17	12
Corn 6N1	1	1	20	49	57	58	59	52	53
Corn 6N2	1	1	---	1	---	---	---	---	---
Corn 6M1	1	1	0	5	9	6	6	0	1
Corn 6M2	1	0	---	1	1	1	1	1	1
Corn 6S1	0	1	---	0	2	3	4	4	1
Corn 6S2	6	8	---	15	9	4	2	1	0

Table B-18. N-NO_3 of tile drain effluent on Hullinger Farm in 1972.

(ppm)

	Drain												
Date	3N	4N	4M	4S	5N	5M	5S	5AN	5AM	5AS	6N	6M	6S
6-28											0.1		
6-29											0.1		
6-30											0.1		
7-3													
7-5													
7-7					0.4	0.3			0.2		0.4	0.2	
7-10											0.1	0.1	
7-11	0.1	0.4	0.3		0.3	0.2		0.4	0.5		0.5	0.3	
7-12													
7-13		0.9	0.2		0.6	0.5		1.6	0.8		0.7	0.2	
7-14											0.1	0.1	
7-17		0.7	0.6		0.5			0.6	0.4		1.3	0.4	
7-18		0.6	0.6		0.5			0.2			1.4	0.4	
7-19		0.6	0.4		1.1	1.2		0.6	0.5		1.3	0.5	
7-20		0.5	0.4		1.6	0.9		0.3	0.2		1.2	0.6	
7-21		0.7	3.7		1.7	1.2		2.4	5.5	1.8	1.9	2.3	
7-22		0.8	2.9		1.4	1.0		3.4	1.9		2.8	1.6	
7-25		0.5	4.4		0.9			2.0	1.4		2.4	3.0	
7-26		0.5	1.0		5.3	6.4	3.2	5.3	8.0	3.7	2.4	1.1	
7-27		0.6	1.0		4.2	6.0	3.2	5.5	8.0	3.1	3.4	4.3	1.6
7-28		0.7	0.8		5.0	5.8	3.5	5.4	5.6	3.4	0.1	3.4	
7-31		0.5	0.9		3.4			5.7	3.9		3.8		
8-1		0.6	0.8		2.7			5.3	4.5		112.8		
8-3	0.1	0.7	0.6		8.3	14.4	6.1	9.2	11.3	6.0	3.1	3.2	
8-4	0.1	0.9	0.7		5.4	15.8	6.1	9.0	13.2	5.7	8.3	5.4	3.6
8-7										0.1	0.1	0.1	
8-8										0.1	0.1	0.1	
8-9	0.2	0.9	0.8		6.3	16.4	12.8	14.2	9.1	5.5	6.1		
8-10	0.1	0.8	0.8		9.1	19.4	6.1	17.3	11.0	4.9	9.1	7.6	
8-11	0.2	0.8	0.8	5.7	7.3	16.1	6.9	17.3	9.4	5.0	5.1	5.4	

Table B-18. N-NO_3 of tile drain effluent on Hullinger Farm in 1972 (Continued).

(ppm)

						Drain							
Date	3N	4N	4M	4S	5N	5M	5S	5AN	5AM	5AS	6N	6M	6S
8-15		1.4	3.4					15.2	8.1				
8-16		1.4	3.6	5.2				14.5	6.8				
8-17		1.4	4.8	1.1	7.5	21.6	21.7	8.6	7.6		3.9		
8-18	0.4	2.3	20.8		5.3	23.2	7.5	9.7	10.5		5.8	8.0	
8-21	0.1	0.8	3.3		4.3	13.8		13.1	10.0		5.6	6.2	
8-22	0.1	1.1	3.3		3.9	8.1		12.2	9.5		3.9	5.6	
8-24		0.8	3.1		4.0	23.0		13.4	9.6		5.0	6.6	
8-25		0.6			4.3	18.5		13.7	10.3		5.1	8.4	
8-28		0.7	4.2		3.7			15.0	7.1		5.2		
8-30		1.1	4.9		6.1	24.3			6.5		10.0	19.0	
8-31		0.7	4.5		5.2	24.1		18.0	11.0		6.1	7.6	
9-1		0.6	7.5		4.2	20.7		17.5	11.4		5.5	6.7	
9-2		0.8	6.2		3.9	16.7		18.1	11.4		5.7	7.9	
9-3		0.7	6.6		4.0	8.7		19.0	10.3		6.7		
9-4		1.1	6.2		4.9			19.0	9.7				
9-5		0.8	5.4		5.5	18.1	11.3	19.4	9.8		8.9	7.8	
9-7	0.8	1.0	6.5		5.1			18.6	8.7				
9-8	0.1	0.6	5.0		3.0			17.3					
9-11		0.6	3.7		2.8								
9-12			2.9										
9-13		0.5	4.3		5.0	10.8							
9-14		0.4	5.5		3.9	9.9			11.1				
9-15	0.1	0.5	5.6		3.9			10.2	9.4				
9-16		0.3	6.2		3.6			18.8	10.0				

Table B-19. N-NO_3 of tile drain effluent on Hullinger Farm in 1973.

(ppm)

	Drain							
Date	4N	4M	5N	5M	5AN	5AM	6N	6M
6-18								
6-19								
6-20								
6-21	1.5	4.3	3.6	18.8	9.7	32.8	6.6	6.6
6-22	2.0	0.7	1.4	5.5	9.5	13.0	2.4	3.3
6-25	0.8	4.1	3.0		5.5	21.8	4.0	3.0
6-26								
6-27	1.2	2.5	2.2	9.2	9.0	23.2	3.0	3.3
6-28								
6-29	1.9	4.0	4.9		9.3	31.0	7.0	5.7
7-2	1.1	1.7	3.6		8.8	31.5	6.6	5.0
7-3								
7-4	1.0	0.6	4.4		8.4	34.3	7.7	5.5
7-5								
7-9		1.3	4.5		6.6	21.3	9.3	
7-12			5.2				11.0	
7-13	0.3	3.6	4.5	5.1	8.4	29.1		5.7
7-16	1.1	3.4	3.4	18.5	9.3	28.9	9.1	5.8
7-18	1.2	3.7	3.5	16.1	8.4	33.2	9.1	5.2
7-19								
7-20	1.2	3.5	3.5	16.1	8.2	27.8	8.6	5.2
7-24	1.1	3.3	3.0	16.3	8.3	31.4	9.5	5.3
7-25								
7-26	1.1	3.3	3.0	16.1	7.8		9.8	4.7
7-27								
7-30	1.2	3.5	3.3		7.5	29.5	15.1	6.7
8-1								
8-2	1.3	3.2	3.1	7.6	8.7	29.9	16.1	4.5
8-6	1.1	3.5	3.1		7.4	28.1	16.6	
8-7								
8-8	1.1	3.5	3.0		8.4	31.7	18.5	
8-9								
8-10	1.7	4.1	3.7	14.9	9.2	27.9	18.0	7.1
8-13	1.1	3.9	2.4	10.9	8.6	24.8	11.2	4.8
8-14								
8-15	1.0	3.2	1.7	9.1	6.4	18.7	8.6	4.1
8-16								
8-17	1.0	3.0	1.7	7.5	5.5	17.5	8.6	5.7
8-20	0.9	2.8	1.7	5.7	4.9	16.6	11.1	3.5
8-21								
8-22	0.9	4.0	1.7	11.1	5.2	16.6	12.3	4.6
8-23								
8-27	1.0	3.4	1.7	8.1	4.7	13.5	10.2	3.1

Table B-19. N-NO$_3$ of tile drain effluent on Hullinger Farm in 1973 (Continued).

(ppm)

Date	Drain 4N	4M	5N	5M	5AN	5AM	6N	6M
8-28								
8-29	0.8	3.2	1.7	1.5	5.2	11.2	11.8	3.1
9-3	0.8	2.3	1.4		4.8	10.0	11.1	3.4
9-4								
9-5	0.8	3.1	1.6		5.0	9.5	12.7	3.5
9-6								
9-7	0.7	4.2	1.0	4.4	5.2	9.8	12.3	3.6
9-12	0.7	4.0	1.5	2.8	5.2	9.1	13.9	4.5
9-13								
9-14	0.8	3.8	1.6	2.6	4.8	9.8	14.8	4.8

Table B-20. Initial and final soil tests in manure plots 1972 for $N\text{-}NO_3$.

(ppm)

		30 cm		60 cm		90 cm		120 cm	
		Before	After	Before	After	Before	After	Before	After
A1 Corn	120 T/A	67.8	22.3	3.0	37.3	1.1	43.9	1.6	43.9
A2 Corn	240 T/A	.0	17.7	1.8	8.7	1.1	.2	1.9	35.4
A3 Bare	0 T/A	10.9	8.8	9.8	5.7	2.4	11.8	3.4	5.8
A4 Corn	60 T/A	38.5	6.2	3.0	3.0	.3	12.1	.9	25.4
A5 Corn	0 T/A	9.9	2.9	4.2	.9	.1	1.4	.5	7.2
A6 Corn	120 T/A	60.5	43.7	5.0	48.4	3.2	47.9	1.7	3.4
B1 Corn	0 T/A	22.3	2.5	.0	1.5	1.1	1.6	.4	4.8
B2 Corn	60 T/A	58.3	10.2	24.4	3.0	2.5	2.5	.3	7.6
B3 Bare	60 T/A	24.0	18.5	13.8	3.2	1.4	8.8	.1	9.6
B4 Corn	120 T/A	125.0	30.0	1.8	9.6	.9	5.4	.6	10.5
B5 Corn	240 T/A	146.2	46.7	5.0	29.4	2.3	46.7	1.6	25.5
B6 Corn	60 T/A	10.8	5.6	1.4	2.4	.2	.3	.1	4.4
C1 Corn	240 T/A	.0	4.8	5.4	1.8	3.3	2.9	2.6	3.2
C2 Corn	120 T/A	16.9	23.0	3.8	27.8	1.5	37.8	.3	65.5
C3 Bare	120 T/A	70.0	25.5	2.6	14.8	1.3	11.3	.5	17.9
C4 Corn	0 T/A	124.9	3.7	7.1	2.7	1.8	2.6	1.4	3.4
C5 Corn	60 T/A	23.9	7.6	4.1	1.8	1.1	4.8	.1	5.5
C6 Corn	0 T/A	9.0	14.8	2.9	3.2	1.0	5.6	2.3	10.8
D1 Corn	60 T/A	43.7	13.0	2.5	6.7	.9	16.1	1.7	45.5
D2 Corn	0 T/A	13.5	3.8	3.2	1.0	1.0	2.2	.4	8.8
D3 Bare	240 T/A	41.2	30.5	3.9	25.1	2.8	.0	1.1	9.2
D4 Corn	240 T/A	19.7	81.8	5.9	27.5	1.1	58.8	.4	45.5
D5 Corn	120 T/A	15.2	6.4	4.2	4.5	3.1	30.0	1.8	28.5
D6 Corn	240 T/A	38.7	82.7	7.1	84.3	4.4	84.3	1.2	61.8
E1 Sudan Grass	0 T/A	5.9	4.0	1.9	.7	.1	.8	.4	3.6
E2 Sudan Grass	240 T/A	13.6	17.1	2.2	27.5	5.6	10.2	.1	.6
E3 Bare	0 T/A	4.7	12.0	.3	12.2	.4	9.6	.2	9.9
E4 Sudan Grass	120 T/A	12.6	9.9	2.0	1.7	.4	1.2	.6	9.3
E5 Sudan Grass	0 T/A	12.7	4.2	1.3	.7	.4	.6	1.1	1.2
E6 Sudan Grass	60 T/A	31.8	11.0	.2	1.6	.3	.7	.5	12.7
F1 Sudan Grass	120 T/A	4.8	12.7	.5	18.1	1.1	18.1	.1	9.1
F2 Sudan Grass	60 T/A	3.6	8.0	1.2	2.6	.3	2.4	.1	1.0
F3 Bare	60 T/A	4.6	70.5	.1	25.7	.2	14.8	.2	14.1
F4 Sudan Grass	0 T/A	10.2	3.3	.7	.8	1.2	.1	.3	.7
F5 Sudan Grass	240 T/A	47.5	5.7	2.1	8.6	.6	27.5	.3	30.8
F6 Sudan Grass	120 T/A	26.0	9.0	.4	9.7	.2	8.2	1.4	5.4
G1 Sudan Grass	240 T/A	15.0	8.3	1.4	6.8	2.0	5.6	.7	2.5
G2 Sudan Grass	120 T/A	3.6	6.7	1.8	12.5	1.0	12.8	1.3	4.0
G3 Bare	120 T/A	11.7	10.2	2.2	7.2	1.2	4.1	1.0	6.9
G4 Sudan Grass	240 T/A	12.3	7.3	2.4	2.5	.9	1.7	1.6	.1
G5 Sudan Grass	60 T/A	18.6	6.9	1.3	20.8	1.4	10.3	1.6	8.5
G6 Sudan Grass	0 T/A	4.4	2.2	1.5	.6	1.5	1.8	.6	4.4
H1 Sudan Grass	60 T/A	11.0	32.4	4.6	6.5	2.8	3.4	.9	5.4
H2 Sudan Grass	0 T/A	2.2	3.4	1.6	.8	2.2	1.4	.8	2.0
H3 Bare	240 T/A	5.2	14.5	2.8	.6	1.7	1.0	1.4	.5
H4 Sudan Grass	60 T/A	3.8	9.1	1.7	2.8	1.0	3.2	1.3	22.9
H5 Sudan Grass	120 T/A	72.3	4.9	2.4	4.0	1.6	9.0	9.9	38.4
H6 Sudan Grass	240 T/A	37.7	40.4	2.8	3.6	1.3	25.4	1.4	38.4

Table B-21. N-NO$_3$ in the manure plots in 1972 collected from ceramic samplers at 106 cm.

(ppm)

	Date								
	7-14	7-22	7-28	8-4	8-10	8-19	8-23	9-7	9-18
Bare (0)[a] A3	—	1	10	74	74	74	38	41	36
Bare (0)[a] E3	—	7	8	18	34	52	53	61	53
Bare (54)[a] B3	8	8	7	83	145	174	152	145	112
Bare (54)[a] F3	—	1	13	37	50	60	61	66	74
Bare (108)[a] C3	11	47	12	—	106	104	110	84	78
Bare (108)[a] G3	—	—	2	5	18	12	47	71	84
Bare (216)[a] D3	—	22	8	113	—	255	248	226	189
Bare (216)[a] H3	—	—	—	1	1	0	1	1	0
Corn A5	—	49	10	—	130	94	72	18	3
Corn B1	5	8	1	47	65	82	96	73	49
Corn C4	—	—	—	—	—	44	30	—	8
Corn C6	—	—	—	—	—	—	—	—	—
Corn D2	—	5	9	15	34	43	49	65	69
Corn (54)[a] A4	7	11	7	67	86	74	71	60	58
Corn (54)[a] B2	16	—	—	—	—	149	125	140	125
Corn (54)[a] B6	19	23	7	60	63	—	54	—	108
Corn (54)[a] C5	—	—	—	—	—	—	117	154	154
Corn (54)[a] D1	5	7	—	21	41	68	82	101	106
Corn (108)[a] A1	10	3	—	6	15	19	—	—	—
Corn (108)[a] A6	—	21	29	35	67	94	—	—	—
Corn (108)[a] B4	—	—	—	—	—	—	—	—	—
Corn (108)[a] C2	—	18	140	168	120	97	121	97	90
Corn (108)[a] D5	—	—	—	—	—	102	129	—	118
Corn (216)[a] A2	1	7	11	56	124	185	253	—	308
Corn (216)[a] B5	—	93	18	139	211	236	256	—	289
Corn (216)[a] C1	—	6	—	72	—	—	—	—	—
Corn (216)[a] D4	—	40	—	43	65	96	—	164	186
Corn (216)[a] D6	—	—	—	—	—	102	110	154	96
Sudan (0) E1	—	1	3	—	—	21	23	26	9
Sudan (0) E5	—	—	—	—	—	23	73	—	84
Sudan (0) F1	—	29	32	25	6	—	32	—	—
Sudan (0) H2	—	5	6	36	29	26	29	32	2
Sudan (0) G6	5	5	—	—	22	41	42	—	38

Table B-21. N-NO_3 in the manure plots in 1972 collected from ceramic samplers at 106 cm (Continued).

(ppm)

	Date								
	7-14	7-22	7-28	8-4	8-10	8-19	8-23	9-7	9-18
Sudan (54)[a] E6	---	---	---	---	---	68	68	---	48
Sudan (54)[a] F6	---	0	0	---	---	17	12	---	---
Sudan (54)[a] G5	9	6	---	10	---	33	43	61	68
Sudan (54)[a] H1	2	1	0	10	24	2	26	---	22
Sudan (54)[a] H4	---	4	4	---	22	53	64	80	60
Sudan (108)[a] E4	---	---	---	---	---	23	73	---	84
Sudan (108)[a] F4	---	---	---	16	38	48	43	45	22
Sudan (108)[a] G2	0	0	0	0	0	0	1	---	0
Sudan (108)[a] H5	---	5	---	---	115	130	141	---	114
Sudan (108)[a] F5	---	---	---	---	---	7	11	---	45
Sudan (216)[a] E2	---	---	---	---	---	---	---	---	---
Sudan (216)[a] F2	1	1	11	---	---	36	39	35	26
Sudan (216)[a] G1	---	---	---	---	10	25	0	1	4
Sudan (216)[a] G4	---	0	0	---	20	52	76	---	99
Sudan (216)[a] H3	---	---	---	1	1	0	1	1	0

[a] Manure application in mt/ha (dry weight)

Table B-22. Initial and final soil tests in manure plots in 1973 for N-NO_3.

(ppm)

	30 cm		60 cm		90 cm		120 cm	
	Before	After	Before	After	Before	After	Before	After
A1 Corn 120 T/A (72)	71.8	20.2	29.0	9.5	29.4	31.8	18.1	12.6
A2 Corn 240 T/A (72)	57.5	29.5	39.5	18.9	38.0	33.5	22.5	26.9
A3 Bare 0 T/A (72)	19.5	10.5	7.5	7.8	7.3	3.0	6.3	37.3
A4 Corn 60 T/A (72)	34.3	7.5	19.5	3.1	10.5	9.8	4.9	3.4
A5 Corn 0 T/A (72)	30.0	4.8	21.3	5.8	11.4	2.3	9.5	22.3
A6 Corn 120 T/A (72)	52.0	37.0	16.3	55.5	60.0	77.0	21.1	44.5
B1 Corn 0 T/A (72)	15.5	4.0	5.0	2.3	4.5	2.8	3.5	2.5
B2 Corn 60 T/A (72)	47.0	17.1	18.8	18.4	20.0	25.0	15.0	26.4
B3 Bare 60 T/A (72)	35.0	17.0	20.0	17.0	21.0	18.3	18.0	27.4
B4 Corn 120 T/A (72)	71.8	20.8	33.8	16.3	26.3	17.5	19.1	8.4
B5 Corn 240 T/A (72)	113.8	48.3	65.0	22.9	23.8	42.8	15.5	28.8
B6 Corn 60 T/A (72)	46.8	7.1	17.3	5.0	4.3	4.5	3.1	10.4
C1 Corn 240 T/A (72)	60.0	55.8	25.3	44.5	17.5	26.3	1.0	20.0
C2 Corn 120 T/A (72)	34.5	30.0	35.0	35.5	9.9	34.3	23.3	11.9
C3 Bare 120 T/A (72)	43.0	39.5	35.0	34.5	25.8	24.5	21.8	30.0
C4 Corn 0 T/A (72)	31.3	3.0	14.5	2.1	5.9	2.4	2.9	1.4
C5 Corn 60 T/A (72)	33.0	12.0	12.0	4.5	11.2	15.8	4.8	1.6
C6 Corn 0 T/A (72)	37.5	17.6	23.3	25.5	10.6	11.8	5.8	17.4
D1 Corn 60 T/A (72)	37.0	45.8	20.5	42.0	6.3	31.3	8.1	22.3
D2 Corn 0 T/A (72)	20.8	2.3	6.2	4.0	5.2	2.5	3.5	8.3
D3 Bare 240 T/A (72)	35.0	55.8	49.3	38.3	36.3	41.8	46.3	29.5
D4 Corn 240 T/A (72)	65.0	62.0	38.3	66.8	46.3	55.8	15.3	27.0
D5 Corn 120 T/A (72)	60.5	42.0	30.8	46.8	64.5	64.8	11.8	28.8
D6 Corn 240 T/A (72)	61.3	103.8	28.3	65.0	44.5	50.8	18.6	9.5
E1 Corn 0 T/A	25.0	3.6	8.0	5.6	4.5	4.8	3.5	10.0
E2 Corn 240 T/A	120.5	92.0	77.3	37.5	30.0	25.8	26.8	13.8
E3 Bare 0 T/A	27.5	14.5	14.5	17.0	11.3	11.3	10.6	11.9
E4 Corn 120 T/A	100.8	67.0	34.5	62.5	27.0	57.8	16.3	21.0
E5 Corn 0 T/A	21.8	3.9	7.0	2.3	6.5	4.0	5.5	1.3
E6 Corn 60 T/A	65.8	41.3	23.0	33.5	16.3	44.3	5.6	10.4
F1 Corn 120 T/A	100.8	77.0	48.5	99.3	33.8	49.5	10.0	4.1
F2 Corn 60 T/A	55.8	27.0	16.8	49.3	9.3	54.5	5.8	.0
F3 Bare 60 T/A	76.3	52.0	37.3	39.3	20.5	16.3	15.3	.0
F4 Corn 0 T/A	32.5	4.9	12.5	3.4	4.0	2.5	3.1	2.4
F5 Corn 240 T/A	132.0	59.5	43.8	65.5	47.8	57.8	18.6	24.8
F6 Corn 120 T/A	62.0	63.3	24.5	67.5	30.8	40.8	15.5	13.3
G1 Corn 240 T/A	95.0	54.5	28.7	50.8	26.3	55.8	21.1	28.5
G2 Corn 120 T/A	82.5	31.3	66.8	22.0	67.0	42.0	16.5	27.4
G3 Bare 120 T/A	67.0	81.8	21.3	27.5	16.4	25.5	11.3	35.8
G4 Corn 240 T/A	98.3	60.0	26.3	22.5	10.3	27.0	13.0	23.1
G5 Corn 60 T/A	101.5	65.8	47.0	80.5	24.5	37.0	15.1	27.8
G6 Corn 0 T/A	26.5	6.9	11.3	1.5	8.1	3.5	3.0	2.8
H1 Corn 60 T/A	98.3	32.0	25.3	67.0	11.2	35.0	9.1	14.1
H2 Corn 0 T/A	19.5	3.5	7.5	2.8	7.0	3.9	3.2	1.3
H3 Bare 240 T/A	107.5	70.0	11.8	45.8	10.8	45.5	2.1	34.5
H4 Corn 60 T/A	46.8	18.5	7.5	26.3	9.0	13.5	7.9	10.1
H5 Corn 120 T/A	52.0	41.3	26.3	55.0	23.8	45.5	18.0	17.5
H6 Corn 240 T/A	63.8	70.0	27.8	48.3	39.5	30.8	19.8	23.3

Table B-23. N-NO_3 in manure plots in 1973 from ceramic samplers at 106 cm depth. Manure application rates in mt/ha (dry weight).

(ppm)

	Date					
	6-30	7-17	7-30	8-10	8-23	9-5
	Manure Applied Only in 1972					
Bare (0) A3	13	14	19	37	37	50
Bare (54) B3	88	112	---	148	181	---
Bare (108) C3	124	248	---	---	---	---
Bare (216) D3	275	316	---	283	223	236
Corn (0) A5	---	116	---	115	137	109
Corn (0) B1	22	24	19	21	21	25
Corn (0) C4	34	34	28	22	17	21
Corn (0) C6	85	---	---	65	76	42
Corn (0) D2	17	20	17	14	19	47
Corn (54) A4	31	31	---	38	41	47
Corn (54) B2	20	135	104	---	104	99
Corn (54) B6	25	27	---	---	15	11
Corn (54) C5	52	52	171	37	32	8
Corn (54) D1	49	67	57	109	86	99
Corn (108) A1	113	248	---	173	133	125
Corn (108) A6	103	145	---	---	163	208
Corn (108) B4	---	---	---	80	88	15
Corn (108) C2	69	24	59	61	71	102
Corn (108) D5	96	255	---	285	285	158
Corn (216) A2	153	149	---	119	50	87
Corn (216) B5	---	217	---	184	163	---
Corn (216) C1	107	135	115	---	102	---
Corn (216) D4	93	207	---	242	208	236
Corn (216) D6	---	231	---	---	229	18
	Manure Applied in Both 1972 and 1973					
Bare (0) E3	56	74	97	106	104	115
Bare (54) F3	110	127	---	153	157	194
Bare (108) G3	45	69	---	75	163	209
Bare (216) H3	27	30	1	129	---	7
Corn (0) E1	38	34	29	20	10	17
Corn (0) E5	42	36	---	42	34	17
Corn (0) F4	51	30	21	18	18	19
Corn (0) G5	26	---	32	356	10	4
Corn (0) H2	21	20	12	9	7	7
Corn (54) E6	23	110	80	86	62	23
Corn (54) F2	44	34	32	34	39	---
Corn (54) H4	---	---	---	---	---	---
Corn (54) G5	---	143	---	152	123	81
Corn (54) H1	18	23	28	40	57	66
Corn (108) E4	107	73	---	82	106	52
Corn (108) F1	65	128	102	105	102	84

Table B-23. N-NO$_3$ in manure plots in 1973 from ceramic samplers at 106 cm depth. Manure application rates in mt/ha (dry weight) (Continued).

(ppm)

	Date					
	6-30	7-17	7-30	8-10	8-23	9-5
Corn (108) F6	116	181	---	178	163	37
Corn (108) G2	70	---	164	144	125	166
Corn (108) H5	76	110	---	---	124	134
Corn (216) E2	138	173	---	429	253	298
Corn (216) F5	121	262	233	---	241	64
Corn (216) G1	111	124	---	152	128	157
Corn (216) G4	54	44	85	60	63	9
Corn (216) H6	---	---	---	---	---	---

Table B-24. Electrical conductivity of samples withdrawn from ceramic cups (106 cm depth) in manure plots in 1972. Manure application rates in mt/ha (dry weight).

(mmho/cm)

	Date								
	7-14	7-22	7-28	8-4	8-10	8-19	8-23	9-7	9-18
Bare (0) A3	---	1.3	1.4	1.8	2.6	2.5	2.2	2.0	2.5
Bare (0) E3	---	3.1	3.2	3.4	4.3	4.7	4.5	4.3	4.7
Bare (54) B3	2.9	3.1	3.9	3.6	4.7	4.7	5.2	4.9	5.1
Bare (54) F3	---	3.2	3.5	3.3	4.3	4.1	4.4	4.3	4.3
Bare (108) C3	4.5	3.0	4.1	---	4.4	4.7	4.5	4.3	4.5
Bare (108) G3	---	---	2	5	18	12	47	71	84
Bare (216) D3	---	3.3	4.0	5.5	---	5.8	6.3	6.1	5.5
Bare (216) H3	---	---	---	3.8	4.7	4.4	4.9	5.0	5.3
Corn (0) A5	---	2.0	2.8	---	3.0	3.3	3.8	3.6	3.5
Corn (0) B1	3.6	3.1	3.2	3.4	3.9	4.2	4.1	3.9	4.1
Corn (0) C4	---	---	---	---	---	3.7	4.0	---	3.8
Corn (0) C6	---	---	---	---	---	---	---	---	---
Corn (0) D2	---	3.6	4.2	3.5	4.7	4.1	4.4	4.4	5.0
Corn (54) A4	2.4	1.7	2.1	2.5	2.9	2.9	3.0	2.6	3.1
Corn (54) B2	4.1	---	---	---	---	4.6	5.2	4.7	4.9
Corn (54) B6	4.1	3.3	3.8	4.5	4.5	---	4.1	---	4.1
Corn (54) C5	---	---	---	---	---	---	4.7	4.6	4.1
Corn (54) D1	4.5	3.6	---	3.2	4.5	4.6	4.6	4.4	4.7

Table B-24. Electrical conductivity of samples withdrawn from ceramic cups (106 cm depth) in manure plots in 1972. Manure application rates in mt/ha (dry weight) (Continued).

(mmho/cm)

		Date								
		7-14	7-22	7-28	8-4	8-10	8-19	8-23	9-7	9-18
Corn (108)	A1	2.7	2.2	---	2.5	3.5	3.9	---	---	---
Corn (108)	A6	---	2.9	4.1	4.2	4.3	4.5	---	---	---
Corn (108)	B4	---	---	---	---	---	---	---	---	---
Corn (108)	C2	---	3.4	4.2	4.2	4.3	4.7	4.8	3.9	4.6
Corn (108)	C3	4.5	3.0	4.1	---	4.4	4.7	4.5	4.3	4.5
Corn (108)	D5	---	---	---	---	---	4.7	5.4	---	5.8
Corn (216)	A2	2.0	2.8	3.6	4.8	4.7	5.4	6.7	---	7.5
Corn (216)	B5	---	3.0	4.3	5.5	5.4	5.7	7.1	---	7.4
Corn (216)	C1	---	2.8	---	4.8	---	---	---	---	---
Corn (216)	D4	---	2.8	---	3.9	3.9	4.5	---	5.3	5.3
Corn (216)	D6	---	---	---	---	---	4.2	4.8	4.7	4.6
Sudan (0)	E1	---	2.2	3.3	---	---	3.9	3.8	3.9	3.8
Sudan (0)	E4	---	---	---	---	---	3.0	4.3	---	4.6
Sudan (0)	F1	---	4.4	4.9	4.5	2.6	---	3.8	---	---
Sudan (0)	H2	---	3.8	3.9	3.2	4.2	4.7	3.9	4.2	4.1
Sudan (0)	G6	3.1	3.8	---	---	3.8	3.9	4.1	---	4.6
Sudan (54)*	E4	---	---	---	---	---	3.9	4.3	---	4.1
Sudan (54)*	F6	---	1.8	2.0	---	---	2.9	3.0	---	---
Sudan (54)*	G5	5.0	4.0	---	4.6	---	5.0	5.0	5.6	5.1
Sudan (54)*	H1	2.8	3.5	4.0	3.9	---	4.9	5.2	---	5.6
Sudan (54)*	H4	---	3.7	4.5	---	4.4	5.1	5.0	4.6	5.0
Sudan (108)*	E4	---	---	---	---	---	3.0	4.3	---	4.6
Sudan (108)*	F4	---	---	---	4.9	4.4	4.5	4.1	4.3	4.3
Sudan (108)*	G2	4.8	6.6	5.4	5.4	5.0	4.7	4.1	---	5.8
Sudan (108)*	H5	---	3.5	---	---	4.7	5.5	5.1	---	5.8
Sudan (108)*	F5	---	---	---	---	---	3.7	4.1	---	4.7
Sudan (216)*	E2	---	---	---	---	---	---	---	---	---
Sudan (216)*	F2	3.4	2.4	3.7	---	---	4.3	4.6	4.1	4.7
Sudan (216)*	G1	---	---	---	---	4.7	5.3	5.3	5.4	4.7
Sudan (216)*	G4	---	3.9	3.9	---	4.2	4.8	5.1	---	5.5
Sudan (216)*	H3	---	---	---	3.8	4.7	4.4	4.9	5.0	5.2

Table B-25. Electrical conductivity of samples withdrawn from ceramic cups (106 cm depth) in manure plots in 1973. Manure application rates in mt/ha (dry weight).

(mmho/cm)

	Date					
	6-30	7-17	7-30	8-10	8-23	9-5
	Manure applied only in 1972					
Bare (0) A3	1.2	0.9	0.9	1.0	1.1	1.1
Bare (54) B3	3.4	3.8	---	3.6	3.7	---
Bare (108) C3	3.7	4.1	---	---	---	---
Bare (216) D3	5.4	6.3	---	6.1	5.7	5.3
Corn (0) A5	---	4.7	---	6.9	7.2	7.8
Corn (0) B1	3.3	3.6	3.1	4.0	3.7	3.7
Corn (0) C4	2.3	2.8	3.6	2.8	2.7	2.7
Corn (0) C6	3.7	---	---	4.4	5.2	5.6
Corn (0) D2	3.7	3.8	3.8	3.8	3.9	4.0
Corn (54) A4	2.2	2.2	---	3.0	2.7	2.4
Corn (54) B2	4.2	4.3	4.2	---	4.5	4.7
Corn (54) B6	3.2	4.4	---	---	3.2	3.8
Corn (54) C5	2.7	3.0	6.4	2.8	2.7	3.5
Corn (54) D1	3.7	3.8	4.0	4.3	4.5	4.8
Corn (108) A1	3.7	4.7	---	5.2	5.3	5.2
Corn (108) A6	4.2	6.9	---	---	5.6	6.0
Corn (108) B4	---	---	---	4.0	4.7	5.4
Corn (108) C2	4.1	4.3	4.3	4.4	4.8	4.7
Corn (108) D5	4.5	5.6	---	6.3	6.8	8.0
Corn (216) A2	5.2	4.5	---	4.7	3.2	4.8
Corn (216) B5	---	7.2	---	6.2	6.1	---
Corn (216) C1	4.8	5.0	5.0	---	5.8	---
Corn (216) D4	5.1	5.5	---	6.9	6.7	7.0
Corn (216) D6	---	7.2	---	---	9.4	9.9
	Manure applied in both 1972 and 1973					
Bare (0) E3	3.7	3.8	4.0	4.0	4.0	3.9
Bare (54) F3	4.4	4.3	---	4.3	4.4	4.8
Bare (108) G3	4.1	5.2	---	4.7	4.9	5.3
Bare (216) H3	4.9	7.7	5.5	5.5	---	5.8
Corn (0) E1	3.2	3.3	3.4	3.4	3.4	3.3
Corn (0) E5	2.9	2.6	---	2.7	2.7	2.8
Corn (0) F4	3.1	3.3	3.4	3.5	3.6	3.3
Corn (0) G6	3.8	---	5.6	6.2	5.4	6.3
Corn (0) H2	3.8	3.8	4.1	4.1	4.1	4.1
Corn (54) E6	2.0	5.7	5.3	5.2	5.4	4.7
Corn (54) F2	2.8	2.2	2.6	2.2	2.2	---

Table B-25. Electrical conductivity of samples withdrawn from ceramic cups (106 cm depth) in manure plots in 1973. Manure application rates in mt/ha (dry weight) (Continued).

(mmho/cm)

	Date					
	6-30	7-17	7-30	8-10	8-23	9-5
Corn (54) G5	---	4.8	---	5.6	5.2	6.2
Corn (54) H1	3.8	4.3	4.3	4.3	4.4	4.6
Corn (54) H4	---	---	---	---	---	---
Corn (108) E4	6.0	4.4	---	4.4	4.9	6.6
Corn (108) F1	4.8	6.2	4.8	4.9	4.9	4.8
Corn (108) F6	6.2	7.0	---	6.9	4.8	7.2
Corn (108) G2	5.1	---	6.0	5.4	5.7	6.0
Corn (108) H5	3.8	4.3	---	---	5.2	4.7
Corn (216) E2	5.6	5.5	---	6.3	6.6	6.5
Corn (216) F5	4.6	9.6	8.8	---	8.0	7.9
Corn (216) G1	5.9	5.5	---	5.7	5.7	5.8
Corn (216) G4	4.4	5.2	4.3	5.4	4.4	4.3
Corn (216) H6	---	---	---	---	---	---

Table B-26. N-NO_3 from the barrel lysimeters in 1972.

(ppm)

	Date								
Treatment[a]	7-13	7-22	7-28	8-4	8-10	8-18	8-23	9-6	9-20
Check (16)	114	119	73	107	86	67	58	51	31
Check (20)	126	178	136	---	112	107	110	94	54
Check (23)	110	51	100	39	99	86	73	62	43
440 kg/ha ND (1)	---	---	262	22	---	231	205	---	175
440 kg/ha ND (4)	---	44	544	639	620	588	112	---	481
440 kg/ha N (6)	---	---	21	---	226	256	243	212	---
440 kg/ha N (7)	110	199	---	311	270	---	273	238	225
440 kg/ha N (9)	598	134	424	---	371	353	416	338	---
110 kg/ha N (5)	---	65	68	125	86	121	100	90	75
110 kg/ha N (8)	83	444	62	128	145	62	83	103	78
110 kg/ha N (10)	54	87	997	256	134	108	129	130	---
110 kg/ha N (11)	58	72	86	189	130	128	129	113	101
538 mt/ha MD (2)	---	71	49	---	177	150	191	---	252

Table B-26. N-NO_3 from the barrel lysimeters in 1972 (Continued).
(ppm)

Treatment[a]	Date 7-13	7-22	7-28	8-4	8-10	8-18	8-23	9-6	9-20
538 mt/ha MD (3)	---	5	26	81	99	168	537	----	234
538 mt/ha M (14)	24	24	54	---	57	53	39	30	---
538 mt/ha M (17)	---	44	42	26	15	8	5	0	1
538 mt/ha M (21)	---	31	6	29	6	1	0	1	1
269 mt/ha M (13)	112	60	53	60	13	59	54	39	17
269 mt/ha M (19)	7	2	82	98	90	65	47	48	28
269 mt/ha M (22)	---	33	67	92	124	88	88	74	51
134 mt/ha M (15)	---	100	150	107	13	75	72	58	38
134 mt/ha M (18)	75	91	88	105	88	88	74	70	34
134 mt/ha M (24)	---	52	68	63	57	76	61	56	44

[a] N is $Ca(NO_3)_2$ commercial fertilizer. M is manure and D is well drained.

Table B-27. N-NO_3 measured in the barrels in 1973.
(ppm)

Treatment[a]		Date 6-21	6-30	7-16	7-30	8-8	8-23	9-5
Checks	16D	-	-	-	-	-	-	-
	16	-	20	23	-	-	-	-
	20D	-	-	-	-	-	-	-
	20	17	17	-	27	-	-	-
	23D	-	-	-	-	-	-	-
	23	5	24	1[illegible]	-	-	-	-
110 kg/ha $Ca(NO_3)_2$	5D	-	-	-	-	-	-	-
	5	2	25	-	-	-	-	-
	8D	-	-	-	-	-	-	-
	8	44	-	-	-	-	1	7
	10D	-	-	-	-	-	-	-
	10	-	43	-	-	-	-	-
	11D	-	-	1	0	-	1	-
	11	-	80	65	-	-	-	-

Table B-27. N-NO_3 measured in the barrels in 1973 (Continued).
(ppm)

Treatment[a]		Date						
		6-21	6-30	7-16	7-30	8-8	8-23	9-5
440 kg/ha Ca(NO_3)$_2$	1D	–	–	1	–	–	1	–
	1	–	–	–	–	–	–	–
	4D	–	–	200	–	–	100	0
	4	–	45	–	–	–	–	–
	6D	–	–	–	–	–	–	–
	6	68	54	170	–	–	–	–
	7D	–	–	0	–	–	–	–
	7	225	214	–	–	–	–	–
	9D	–	–	38	–	–	–	–
	9	425	396	–	–	169	–	–
	12D	–	–	–	0	–	–	–
	12	178	215	224	–	–	–	–
54 mt/ha manual	15D	–	–	23	13	–	–	–
	15	–	–	–	–	–	–	–
	18D	–	–	–	–	–	–	–
	18	18	9	–	–	–	–	–
	24D	–	–	–	–	–	–	–
	24	2	19	11	–	–	–	–
	13D	–	–	1	–	–	0	–
108 mt/ha manual	13	7	7	–	–	–	–	–
	19D	–	–	–	–	–	–	–
	19	3	0	0	0	–	–	–
	22D	–	–	–	–	–	–	–
	22	–	6	–	–	–	–	–
216 mt/ha	2D	336	376	189	–	–	2	–
	2	–	–	–	–	–	–	–
	3D	248	294	264	–	–	86	–
	3	257	234	–	–	183	–	–
	14D	–	–	–	–	–	–	–
	14	1	1	–	1	–	–	–
	21D	–	–	–	–	–	71	–
	21	0	0	–	–	–	36	27
	17D	–	–	–	–	–	–	–
	17	2	0	–	1	28	–	–

[a] D refers to the water collected in the drains. Otherwise the samples were collected from ceramic samples at about 70 cm depth. All treatments were applied in 1972 only.

Table B-28. Electrical conductivity of water samples from the barrel lysimeters in 1972.

(mmho/cm)

	Date								
Treatment[a]	7-13	7-22	7-28	8-4	8-10	8-18	8-23	9-6	9-20
Check (16)	2.8	2.5	2.4	3.2	2.9	3.3	2.3	2.8	2.3
Check (20)	4.0	2.2	3.3	--	3.6	3.3	3.7	3.2	3.7
Check (23)	3.2	2.6	2.9	4.2	3.2	3.0	3.2	3.0	3.2
440 kg/ha ND (1)	--	--	5.1	3.0	--	5.0	4.3	--	5.6
440 kg/ha ND (4)	--	3.0	4.2	6.3	5.5	6.3	6.4	--	7.4
440 kg/ha N (6)	--	--	3.3	--	3.9	4.7	4.7	4.3	--
440 kg/ha N (7)	4.6	3.2	--	5.4	4.2	--	4.9	4.5	4.9
440 kg/ha N (9)	6.7	4.6	5.2	--	5.8	5.8	5.6	5.3	--
110 kg/ha N (5)	--	2.6	2.9	4.2	3.9	3.7	3.9	3.7	4.1
110 kg/ha N (8)	2.9	4.7	3.3	4.6	3.3	3.9	4.1	4.0	4.3
110 kg/ha N (10)	3.1	3.2	4.6	5.9	5.4	5.0	5.4	5.0	--
110 kg/ha N (11)	5.5	4.2	4.4	5.8	4.8	5.4	5.5	4.7	5.4
538 mt/ha MD (2)	--	3.5	3.5	--	6.5	7.2	7.4	--	7.7
538 mt/ha MD (3)	--	2.9	2.3	5.4	6.7	7.3	6.3	--	7.2
538 mt/ha M (14)	3.1	2.5	2.7	--	4.5	4.8	4.8	4.3	--
538 mt/ha M (17)	--	2.7	3.1	3.2	3.9	4.0	4.8	4.6	4.4
538 mt/ha M (21)	--	2.5	3.3	5.0	4.2	5.1	4.6	5.2	5.6
269 mt/ha M (13)	3.1	2.4	2.5	3.9	4.0	4.4	4.5	4.1	4.8
269 mt/ha M (19)	2.6	2.6	2.9	4.9	4.3	4.1	4.2	4.4	4.5
269 mt/ha M (22)	--	2.3	2.9	4.5	4.1	4.4	4.4	4.6	4.6
134 mt/ha M (15)	--	4.6	2.7	5.9	5.1	5.1	4.8	4.5	4.6
134 mt/ha M (18)	3.1	2.6	3.0	4.0	3.6	3.9	3.9	3.8	4.0
134 mt/ha M (24)	--	2.7	3.0	3.9	3.4	3.6	3.5	3.5	3.6

[a] N is $Ca(NO_3)_2$ commercial fertilizer. M is manure, and D is well drained.